TREASURY DEPARTMENT
UNITED STATES PUBLIC HEALTH SERVICE

PUBLIC HEALTH BULLETIN No. 140
JULY, 1924

STUDIES IN ILLUMINATION

I. THE HYGIENIC CONDITIONS OF ILLUMINATION IN CERTAIN POST OFFICES, ESPECIALLY RELATING TO VISUAL DEFECTS AND EFFICIENCY

BY

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PREPARED BY DIRECTION OF THE SURGEON GENERAL

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PART I.

I. INTRODUCTION.

REQUEST FOR A SURVEY.

At the request of the Postmaster General to the Secretary of the Treasury that the United States Public Health Service make a survey of the lighting conditions in the New York post offices, an investigation was made of the particular problems of illumination as they relate to post-office work in general. In addition to this study an attempt was made to determine, if possible, the relationship between the present conditions of illumination in the post offices and the vision of the post-office employees and the relationship between various degrees of illumination and efficiency.

The survey extended over a period of about eight months. Measurements of the illumination, both artificial and natural, actually prevailing in the two post offices were made and tests with different lighting units under different intensities of illumination were carried on.

PERSONNEL OF THE SURVEY.

Surg. Louis Schwartz was detailed to the Office of Industrial Hygiene and was placed in immediate charge of the survey party on account of his special qualifications in ophthalmology. Physicist James E. Ives, who had had previous experience in the subject of illumination, was given full charge of the illumination studies, and Scientific Assistant Norris P. Bryan was detailed to the survey party for occupational studies. The survey party was continually under the direct supervision of Surg. L. R. Thompson, medical officer in charge of the Office of Industrial Hygiene and Sanitation.

* Manuscript submitted December, 1923.

The statistical studies were made by Assistant Statisticians Frank M. Phillips and Rollo H. Britten, under the general supervision of Statistician Edgar Sydenstricker, in charge of the statistical office of the Public Health Service. Passed Asst. Surg. R. C. Williams, Pharmacist William G. Beucler, and other members of the Office of Industrial Hygiene and Sanitation were frequently called into consultation in the preparation of the report.

ACKNOWLEDGMENTS.

In drawing up the general plan of work, to the end that the survey might be made as complete as possible, the illuminating engineers of a number of the large manufacturing concerns interested in lighting were repeatedly consulted, and the Public Health Service desires to acknowledge with gratitude the valuable assistance of these companies, both in consultation, and in lending and installing lamps and fixtures. The service is especially appreciative of the assistance of the Edison Lamp Works, Newark, N. J.; the Westinghouse Lamp Co., New York City; the Holophane Glass Co., New York City; the Ivanhoe-Regent Works, Cleveland, Ohio; the Duplex Lighting Works, New York City; the Mitchell-Vance Co. (Inc.), New York City; and the following engineers and representatives of these companies: Messrs. G. H. Stickney, A. L. Powell, J. H. Kurlander, D. W. Atwater, F. W. Mathieu, Davis H. Tuck, Harold W. Hahn, and Arthur Miller. The service also desires to acknowledge the complete cooperation which was given at all times by the Postmaster General, Dr. Hubert Work, the post-office authorities, and the post-office employees, without whose unreserved help the survey would have been impossible.

PLAN OF WORK.

In 1920 Acting Asst. Surg. Harold B. Wood was detailed by the Office of Industrial Hygiene and Sanitation to make a general sanitary survey of a number of post offices. These investigations included 127 post offices in the cities of New York, Brooklyn, Philadelphia, Boston, Detroit, and Chicago. The post offices surveyed included not only the principal post offices in each city but many of the smaller branches. While these surveys were of a general nature, particular attention was paid to the conditions of illumination.

The natural illumination was considered by Doctor Wood to be adequate in only 63 per cent of the post offices examined and the artificial illumination in only 57 per cent of them. Only 34 per cent of the post offices examined were found to have both natural

and artificial illumination of an adequate degree; 15.7 per cent of the post offices examined depended entirely upon gas for artificial illumination. An important point brought out by these surveys was that in the great majority of post offices the general plan of work and the method of handling post office work were much the same. For this reason it was felt that the intimate study of a few large post offices would give more general data than a more curtailed survey of a number of post offices in various cities. Again, it was felt that the selection of a few large post offices was especially desirable because of the considerable number of employees in them from whom large groups could be drawn for study and for eye examinations. For these reasons two post offices in New York City, the old City Hall post office at Broadway and Park Row, and the relatively new general post office at Thirty-second Street and Eighth Avenue were selected. The former building is over 40 years old; the average intensity of illumination in it is low, and artificial illumination is used in it for the most part. This is in contrast with the latter building, which is about 7 years old and has a higher average intensity of artificial illumination; furthermore, a majority of the employees in it work under part or full time daylight.

The general plan of the investigation contemplated three broad sections:

1. *Occupational and process studies:*
   - (*a*) A determination of the kind and character of work performed by all the employees, with the idea of grouping them into occupations according to the nature and intensity of the eye work done.
   - (*b*) A determination of the speed and efficiency of certain groups of employees under different degrees of illumination.
   - (*c*) A determination of the efficiency of certain groups of employees handling envelopes and cards of different colors.
   - (*d*) A study of the economic advantages of increased illumination.
2. *Illumination studies:*
   - (*a*) A consideration of the actual existing conditions of illumination under which the post-office employees were working at the time of the investigation, with measurements, as far as possible, of the actual illumination on the working planes in foot-candles.
   - (*b*) An investigation to determine the most desirable intensity of illumination for various kinds of post-office work.

2. *Illumination studies*—Continued.

(*c*) An investigation to determine the type of lighting unit having the most suitable light distribution for post-office work.

(*d*) The testing of these units after their installation in certain areas of the post office under practical conditions.

(*e*) Special studies to determine the mean illumination for occupational groups, and the actual individual illumination for each worker.

3. *Studies of eye defects among post-office employees:*

Determination of eye defects among post-office employees, chosen so as to represent all occupational groups. This examination included the determination of visual acuity by the use of Snellen cards; the determination of muscular unbalance, inflammatory conditions of the eyes, asthenopia, and refractive errors. The ophthalmoscope was used in all cases in which disease of the internal structure of the eye was suspected.

II. OCCUPATIONAL AND PROCESS STUDIES.

DIVISIONS OF THE POST OFFICE.

The primary function of the Postal Service is to transfer mail from the sender to the addressee. The major activities at all post offices in connection with this function are those of a clearing house—bringing together, dispatching, and delivering mail. To facilitate these activities, mail is divided into two groups—one for delivery within the territory served by the local post office, and one for distribution and dispatch to outside points. These two divisions are officially designated as the delivery and dispatching divisions, respectively. The four other official divisions of work in the post office are the registry division, the money-order division, the cashier's office, and the bookkeeping section.

In the delivery, dispatching, and registry divisions, the handling of mail is based upon the size and shape of pieces, rather than upon a separation according to its official classification. This applies more directly to mail that is not first-class, although even the letter mail is placed in two groups according to the length of the letters.

For a clear view of the processes involved, it seemed desirable to follow the different classes of mail through a representative post office and to picture the work and surroundings of the employees handling them. This was therefore done for the City Hall post office, which was the first of the two post offices to be studied in detail, and which was considered large enough to be representative.

THE DISPATCHING DIVISION.

All mail arrives at the City Hall post office in one of three ways—through the drops; through collection, which gathers a very small percentage of the mail; or from five post office stations whence collections are sent to the City Hall post office for separation and distribution. Mail coming through collections and over the entrance platform goes directly to the distribution section of the post office, located on the mezzanine floor and in the basement. The work on the platform consists largely of manual labor, dragging, carrying, and trucking the mail bags; the only eye work of any detail done on the platform consists in reading the labels on the bags, which are in large typewritten or printed characters.

The first-class mail, on reaching the dispatching division on the mezzanine floor, is dumped on what are known as facing tables, at which the work is done standing. These tables are 36 inches high, and have above their centers either a traveling or a stationary shelf upon which the mail is placed, all the letters being faced the same way. No concentration of vision is required in this work other than to see that all mail is placed in the same relative position, and that each piece is stamped. Those pieces without stamps and those pieces commonly called "slugs," which are so thick that they can not be taken by the stamp cancellation machine, are thrown into a basket and taken to a cancellation table, where the stamps are canceled by hand. This table is similar in height to the facing-up tables, and the work is of a similar nature as far as the eye work is concerned. From the facing-up tables the first-class mail goes directly to the stamp cancellation machines, each operated by one man, who feeds the letters into it. The stamp cancellation machines work automatically, pulling in the letters, one at a time, in rapid succession, and there is no close eye concentration in the process.

From the cancellation machines the first-class mail is taken by hand or by truck, by men called "feeders," to the various separation cases, where the first, or *primary*, separation is made. Each case has a shelf 15 inches deep and 25 inches above the floor, upon which the feeder places the letters, all facing the same way. Immediately above the shelf are the pigeonholes into which the mail is distributed in accordance with its destination. The number of horizontal rows of pigeonholes in a case varies, some cases having as many as nine horizontal rows. All sorting cases for letters are constructed after this fashion, the pigeonholes beginning about 25 inches from the floor and extending in some cases to a total height of 80 inches, so that the bottom of the top row of holes may be 72 inches from the floor. The larger cases have 63 holes in all, 7 in a horizontal row and 9 in a vertical row. The holes are about 7 inches deep. For the first separation 34 pigeonholes are used, beginning at the bottom of the case. These holes are approximately 5 by 5 inches in size, but vary in size in different cases. The width of the cases used varies from 34 to 40 inches. In many instances these cases are backed with wire screens of square mesh, which create a confusing effect upon the eyes of the workers, particularly where lights or active workers are on the other side of the case. The workers are required to stand continuously in front of the cases.[1] The speed of work depends, among other things, on the number of holes used, the character of the writing or printing on the envelopes, and the physical condition of the worker. The letters are held at approximately elbow

[1] This was true when the survey was made. In the larger post offices the workers are now provided with rests which give them some support.

level and inclined toward the worker at an angle of about 10 degrees from the horizontal. In the primary and other separations, it is the aim to have the holes into which the bulk of the mail goes situated to the right and in the lower section of the case, since this arrangement is not only easier for the worker but greatly facilitates the work. The maximum area covered by these pigeonholes is about 15 square feet and the maximum distance from the working position is approximately 20 inches and no shifting of the feet is required to reach all the holes.

From the primary separation cases a "sweeper" takes the mail to the State cases, where the *secondary* separation takes place. This work is conducted in the same manner as the primary separation, the work being similar except for the fact that a few more boxes or compartments may be used. In each case the eye work involved requires the reading of the city and State address on each piece of mail.

At stated periods, which depend upon the time at which mails are to be pouched for the trains, the distributers pause in their sorting work to tie the letters into bundles for the various points for which the trains are destined. Much of this tying is done at the "tie-out" table. "Sweepers," each tying for a definite territory, sweep or gather their mail from the cases, carry it to the table, tie it, see that it is properly marked, and place it on the conveyer which carries it to the pouching table. Other than this there is no interruption in the separating work. The full day is eight hours, divided into two parts by a lunch period.

Special separations are made at cases similar to the others except that additional pigeonholes to a total of 96 are used, carrying the work to the top of the cases. Special delivery and damaged mail in the distribution department is thrown into baskets and taken to the "hospital" or "repair" table. All special delivery first-class mail for distribution from all parts of the post-office building also goes there, where it is sorted and tied by itself, and is then sent to the pouching department to take its place with other first-class mail.

When the first-class mail is separated for distribution outside New York City, it is transported by chute or truck to the pouching department. The work required here is the distribution of packages of various sizes into the proper compartments of a large separation case, commonly known as a "jug." The compartments, or boxes, have openings approximately 12 inches square, arranged in tiers, extending from 3 feet to 10 feet above the floor. The route, or destination, of the package is taken from the uppermost letter, or from a slip inserted on the top of the package, and the package is then thrown into the proper bin or compartment and is later withdrawn from the rear of the case into the mail pouch. The transfer

of the packages from the bins to the pouches takes place whenever the bins become well filled, or at train time. The working table, or shelf, in front of this case, where the mail is dumped for separation, and before which the men stand as they work, is 36 inches high and 36 inches wide. Thus the nearest point of the vertical work plane is 36 inches from the place where the worker holds the package in his hands. Packages are usually held at, or slightly above, elbow level and inclined toward the worker at about 10 degrees to the horizontal while the address is read. The eye work here is twofold—the operator must read the name of the city and the State, or the route, as indicated on the inserted slip, and must then refocus his eye upon the proper bin and watch the package until it has gone into the bin. Thus the eye must constantly change its focus.

Since there are not a sufficient number of holes in the pouching case for the work carried on at this station, pouching racks have been introduced. These racks are constructed of metal pipe upon which rows of bags can be held open at waist level; sometimes they slant upward until the last row of bags, which may be the fifth or sixth row, is about at shoulder level. Mail to be pouched at these racks is brought to the front of them in tubs or trucks. The operations for the racks differ from those for the pouching case only in that, when the tub is almost empty, the operator must bend over and take his parcel from the bottom of the tub, and in that the vertical work plane is eliminated.

The average speed of operation at these racks, shown in Table I, is not rapid. Work at the racks is not constant, most of the work coming between 5 and 8 o'clock at night.

Third-class circular mail for distribution is divided into three categories, known as bulk, all mixed, or part mixed. The bulk mail is almost always sacked by the business house sending it; thus, a large mail-order house will send a number of sacks in each of which the mail matter is destined for from one to nine points. Where precanceled stamps or prepaid methods are used, the cancellation machine is not necessary, and the mail is distributed on a layout table into the number of piles necessary, tied and sent to the pouching section and handled by the same method as first-class mail. From observation of the men doing this work it is estimated that they do considerably less eye work than when handling each piece individually, as in the first-class separations. The greater portion of the time required for handling most of the bulk mail is consumed in tying rather than in separating.

Second, third, and fourth class mail, other than circulars, for distribution is not separated strictly according to class, but according to size of package, everything smaller than an ordinary shoe box going into one group, and the large pieces into another group. All

this mail is canceled on its entrance into the post office, except that which is brought by individual firms in their own trucks and which is conveyed to the basement by chutes and is canceled by a hand stamp. The tables used for cancellation are 37 inches high and vary in area according to their use. The larger mail, after cancellation, is taken to another point in the basement for separation according to its destination. It is first separated into tubs according to certain geographical subdivisions. Each of these tubs is then taken to its own section, where the distribution is similar to that described for the pouching section. These operations, except that of separation, require no eye work other than is necessary to see that the stamp is properly canceled. In separating the mail according to destination the State and city must be read. The work is rather slow, because of the size of the packages handled. The smaller mail, after being canceled, is taken to the large separation cases, sometimes called "jugs," where it is sorted in a manner similar to that described for pouching mail.

THE DELIVERY DIVISION.

A large part of the first-class mail that goes to the dispatching division is addressed to persons or firms in the territory served by the New York post office. This mail is placed in "delivery" pigeonholes in the separation cases, and is regularly collected and taken to the separation cases in the delivery division. Other first-class mail for delivery is received from other city stations or stations outside the city. This latter mail is first taken in pouches to the opening form at the center of the delivery section. There the mail is dumped from the pouches, the bundles are opened, any necessary records are made, and the letters are faced and taken to the separation cases by men who are employed mainly in that work. After separation the mail is pouched and dispatched to its proper destination.

First-class mail for delivery within the territory served by the City Hall post office is separated by routes in what are called "city" cases. These cases and the worker's position and speed of operation are similar to those in the dispatching division. The work involves greater mental activity, however, because for each street number the proper route must be found and the letter must be placed in the corresponding hole; and the separator must read the name and recognize and hold out those pieces destined for lock-and-call boxes, the bank window, and other "holdouts." This work proceeds continuously, the number of workers on these cases increasing or decreasing as the supply of the mail varies. Mail is removed from the rear of the pigeonholes of the city cases by the letter carriers.

The cases at which the carriers arrange the mail to be delivered on their respective routes have each a shelf, 36 inches above the floor, 36 inches wide, and 24 inches deep. The men frequently use stools while routing their mail in order of delivery, although the majority prefer to do their work standing. It is possible to do this work seated, since the cases are only 3 feet wide by 2½ feet high.

Third-class circular mail for delivery is handled in the same way as first-class letter mail. When there is no rush, they both go to the distribution cases together. During any rush period, however, or when a large number of circulars come in at any one time, the third-class circular mail is held until the first-class mail has been separated.

Newspapers and small parcels for delivery at points in the city outside the City Hall district are separated, either in newspaper separation cases having pigeonholes about three times the size of those of the letter cases, or directly into pouches. This work requires the reading of the street address only. The work is done in a standing position, because of the physical activity necessitated by it. The rapidity of handling it depends largely on the condition of the mail as it comes to the separator and on the varying size and shape of the packages. Large separation cases, similar to those used in the pouching of first-class mail, are also used.

Newpapers and small parcels for delivery in the City Hall territory are separated by routes, and afterwards by the carriers on each route, and are taken out of the post office along with the first-class mail. The operations involved are similar to those involved in the handling of first-class mail, except that they are slower, because of the size of the pieces.

Large parcels for delivery at points in the city outside the City Hall district are placed on a large table, 37 inches high, on three sides of which there is a series of bins, one for each station. Separators work around the table, throwing or carrying the packages to their proper bins. From the bins they are pouched and labeled for their proper destinations. The separators are required to read the street address only.

Similar matter for delivery within the City Hall district is separated according to routes, which are much more extensive than those for foot delivery, since such mail is delivered by automobile trucks.

THE REGISTRY DIVISION.

The mail in the registry division requires a procedure similar to that for ordinary mail. The movement of each piece of mail,

however, is much more involved than that of ordinary mail because no piece of registered mail passes from one person to another without a receipt. The pouch bringing mail to the division is receipted for; the first man who handles a piece of mail receives a receipt from the man to whom he gives it, and so on until it reaches the hand of the addressee. Every man working in this section, therefore, is required to do detailed eye work continuously, since the number on the package has to be checked against the record and a new record made. The entire floor space devoted to registered mail is involved in its handling, and movable tables or trucks are used for much of the clerical work. The tables are approximately 40 inches high and the workers usually stand.

THE MONEY-ORDER DIVISION.

Work in the money-order division is entirely of a clerical nature; it involves writing receipts, making records, counting money, etc. The greater part of this work is done at an ordinary office desk, or at a desk suitable for a standing position. The eye work is on a horizontal plane, except where occasionally the worker must refer to a card placed on the wall in front of him.

THE CASHIER'S OFFICE AND STAMP OFFICE.

The work in the cashier's office is similar to the ordinary work of a cashier's office in any line of business that involves bookkeeping, general writing, and similar clerical activities.

The work in the stamp department involves only desk and window work, which may be performed while standing or sitting, and requires, as a rule, eye work on a horizontal plane only. The work consists in handling stamps, post cards, envelopes, and money, and the making of the necessary records.

NEWSPAPER AND PERIODICAL POSTAGE SECTION.

This department receives all newspaper and periodical mail in bulk. The mail is brought from the outside platform to the scales by the regular platform men. The employees of this department then weigh the mail, calculate and collect the postage, and make the required records. The work is performed at typical office desks, in either standing or sitting posture. The work plane is either horizontal or inclined toward the worker at approximately 10 degrees.

THE DIRECTORY SERVICE AND OTHER WORK.

Incidental to the conduct of the regular work, there are numerous minor occupations of interest. The directory service is one of these.

All mail that can not be handled by the delivery division because it is improperly or insufficiently addressed, goes to this group of workers, who search the directories and correct the addresses when possible. If no clue is available, the mail is sent to the general post office for further disposition. This occupation requires very intense eye work. Other work, such as that of the transportation office, the timekeepers, the redirecting clerks, and the superintendent's office, is purely clerical.

PUBLIC CORRIDORS.

Observation of the activities of the public in connection with the post office indicates that it is difficult to classify those activities as far as vision and illumination are concerned.

The facts of importance are that at all points where the public uses the facilities of the post office, as at the drops, lock boxes, or windows, there are moments when more or less intense eye work is necessary. The illumination at these places should be of such character and intensity that even poorly written addresses can be read with ease. Illumination sufficient for detailed eye work should also be provided on the tables and shelves installed for the use of the public.

CLASSIFICATION OF EMPLOYEES INTO OCCUPATIONAL GROUPS.

As already stated in the earlier part of this bulletin, in the general plan of work the occupational groups in the post office were so chosen that each group included employees who were doing eye work of approximately the same amount and intensity. To give a clear idea of the number in each occupational group and of the distribution of the groups in the general classification, Tables III and IV have been prepared, showing the number of employees at the City Hall and the general post offices according to their assignment on January 7 and February 6, 1922, respectively. The figures are approximate, since in many cases the assignment was not fixed. With a view to preparing these tables, certain groups of workers, who were not aware of the fact, were studied as to the actual amount of work done in terms of pieces of mail handled in a minute. The results are set forth in Tables I and II. The results checked what had been learned through observation. In general, they indicate that all first-class mail separation is similar in character, and for this reason first-class mail separation has been considered as belonging to one occupational group, the group which is doing by far the most intensive eye work. This group has been designated as Group 7. Newspaper separators and pouchers of small matter have been

designated as Group 4. Parcel-post separators as a whole are taken as Group 3. To these three groups there are added five others: Those handling mail bags on the platform or inside the building, whose only requirement, other than manual labor, is that of reading a few printed labels; these may be called laborers and are designated as Group 1; facers, hand or machine cancellation feeders, sweepers, or strippers, tie-out men, return-postage workers, workers in storage and supply rooms, and workers on opening tables, designated as Group 2; executives, superintendents, and foremen, designated as Group 5; those doing clerical work, work involving more or less writing, designated as Group 6; and letter carriers, designated as Group 8.

TABLE I.—*Number of pieces of mail handled per minute, during period of observation, by groups of workers in the dispatching division of the New York City Hall post office.*

Kind of work.	Number of pigeonholes.	Number of workers.	Total time (in minutes).	Total number of pieces handled.	Average number per minute.
Primary separation of first-class mail (small envelopes)	34	5	27	1,112	41.2
Secondary separation of first-class mail (small envelopes)	61	4	36	1,185	32.9
Primary separation of first-class mail (long envelopes)	34	3	30	1,007	33.5
Separation of newspapers	126	2	40	460	11.5
Pouching of first-class mail[1]	24	3	15	270	18.0
Primary separation of large parcel post	8 tubs.	5	57½	407	7.0
Secondary separation of large parcel post	variable.	3	44	174	4.0
Checking insured parcel post[2]	.....	2	5	34	6.8

[1] Work here is irregular. During approximately 45 minutes three men worked for a total of 15 minutes.
[2] This is not continuous work. It involves checking lists of insured matter from firms who deliver mail in bulk. One man handles packages while the other checks the lists.

TABLE II.—*Number of pieces of mail handled per minute, during period of observation, by groups of workers in the delivery division of the New York City Hall post office.*

Kind of work.	Number of pigeonholes.	Number of workers.	Total time (in minutes).	Total number of pieces handled.	Average number per minute.
Station separation of first-class mail (small envelopes)	56	6	30	872	29.1
Route separation of first-class mail (small envelopes)[1]	84	6	30	1,082	36.1
Station separation of first-class mail (long envelopes)[2]	56	5	25	901	36.0
Station separation of newspapers	42	6	30	395	13.2
Route separation of newspapers	74	5	25	483	19.3
Route separation of small parcel post into bin or jug	65	4	26½	317	12.0
Station separation of large parcel post (large bins)	32	2	24	142	5.9
Route separation of large parcel post (pouching racks)	(3)	3	30	117	3.9

[1] One worker ran into a lot of window envelopes and dropped from 41 to 32 pieces per minute. Twice during this test workers came upon groups of letters going into two or three pigeonholes.
[2] Two tests made on one girl who was afterwards found to be one of the best on the force.
[3] Floor area, 25 by 50 feet.

TABLE III.—*Number of employees in the various occupational groups at the New York City Hall post office, according to their assignment on January 7, 1922.*

Designation of occupational group.	Occupational groups.	Regulars.		Substitutes.	
1	Laborers, etc	.....	94	.....	8
2	Facers, etc	.....	18	.....	127
	Workers at facing tables	1		66	
	Workers at cancellation machines	3		8	
	Workers at hand cancellation tables	2		5	
	Mechanics	3		0	
	Utility men	0		44	
	Workers at opening tables	9		4	
3	Parcel post separators	.....	75	.....	17
4	Newspaper separators and pouchers of small matter	.....	80	.....	21
5	Executives, superintendents, foremen, etc	.....	23	.....	.....
6	Clerks	.....	314	.....	16
	In registry division	126		0	
	In money-order division	14		0	
	For stamps and cashier's office	22		0	
	Window clerks	41		4	
	Directory searchers	23		2	
	Timekeepers, etc	44		2	
	At redirecting desk	3		0	
	In unpaid department	5		0	
	In office	22		0	
	Foreign list workers	3		0	
	Newspaper postage section clerks	11		0	
7	Letter separators	.....	302	.....	101
8	Carriers	.....	253	.....	69
	Total	.....	1,159	.....	359

TABLE IV.—*Number of employees in the various occupational groups at the New York general post office, according to their assignment on February 6, 1922.*

Designation of occupational group.	Occupational groups.	Regulars.		Substitutes.	
1	Laborers, etc	.....	131	.....	39
2	Facers, etc	.....	133	.....	85
	Workers at facing tables	18		81	
	Workers at cancellation machines	15		2	
	Workers at hand cancellation tables	18		0	
	Workers receiving mail	6		2	
	Workers examining empty equipment	67		0	
	Workers at opening tables	9		0	
3	Parcel post separators	.....	28	.....	17
4	Newspaper separators and pouchers of small matter	.....	239	.....	84
5	Executives, superintendents, foremen, etc	.....	91	.....	.....
6	Clerks	.....	1,049	.....	.....
	In registry division	392		0	
	In money-order division	211		0	
	For stamps and cashier's office	44		0	
	In auditor's office	65		0	
	In assistant postmaster's office	209		0	
	Window clerks	32		0	
	Directory searchers	7		0	
	Timekeepers, etc	89		0	
7	Letter separators	.....	696	.....	325
8	Carriers	.....	169	.....	101
	Unclassified substitutes	.....	.....	.....	81
	Total	.....	2,536	.....	732

HOURS OF WORK.

All the regular employees of the City Hall and general post offices in New York, with the exception of those doing purely clerical work, and of the letter carriers, work in three shifts, or tours, of eight hours each. In general, the shifts rotate, so that a day shift will be followed by a night shift, or by a day-and-night shift, in order that no individual will have all his working hours during the daytime or during the nighttime in the course of the year. The shifts, however, do not necessarily have the same number of workers in them and sometimes, during the busy hours, overlap. In the general post office the shifts are changed every 10 weeks or 2 months. In the City Hall post office the shifts are changed every 30 days in the dispatching division, and every 3 months in the delivery division.

Employees doing purely clerical work, such as the clerks in the financial and executive offices, although working eight hours a day, usually work only during the daytime.

The letter carriers, in these post offices, spend, on an average, from two to two and a half hours each day in the post office setting up their mail, while the remainder of the eight hours of their work day is consumed in delivering it.

III. ILLUMINATION SURVEYS.

MEASUREMENTS OF THE ILLUMINATION.

Measurements of the illumination in the present surveys of the City Hall and general post offices were made with a Macbeth illuminometer, which was frequently checked by comparing it with a reference standard calibrated by the Electrical Testing Laboratories, New York City.

The measurements of the illumination in the City Hall post office were made during December and January, and in the general post office during March and April. The tests of different types of units and different intensities of illumination were continued until the end of June.

In order to find out whether the illumination in other post offices was similar to that in the two post offices studied, post-office buildings in Trenton, N. J., Philadelphia, Pa., and Hartford and New Haven, Conn., were visited and studied. The measurements of illumination in these post offices were made with a foot-candle meter.

ILLUMINATION OF THE NEW YORK CITY HALL POST OFFICE.

SHAPE AND CHARACTER OF THE BUILDING.

The New York City Hall post office building is in the shape of an isosceles triangle, with its apex pointing south. The base of the triangle, running east and west, is about 275 feet long, and its sides are each about 300 feet long. It is built around a triangular court, or well, the base of the triangle formed being about 80 feet long, and the sides 100 feet long. This well is covered by a glass roof, or skylight, at the level of the ceiling of the mezzanine floor. The building is five stories high, with a basement and a sub-basement. The first floor has been converted into two floors by the construction of a mezzanine floor.

The basement, the main floor, the mezzanine floor, and two rooms on the second floor are used by the post office. The rest of the building is occupied by Federal law courts and other Federal offices. In the sub-basement are located the motors for running the lifts and elevators. Plans of the mezzanine, first, and basement floors of the building are appended to this report and are marked plans 1–3.

HISTORY OF THE LIGHTING.

The City Hall post office building was completed in March, 1875. It was lighted by gas until about 1886, when an electric lighting plant was installed. This plant was operated until about 1895. Having been greatly damaged by fire, it was replaced by a comparatively modern plant in 1897, which continued in operation until June 21, 1914, when the present system of buying power from the New York Edison Co. was inaugurated. The conduits, wiring, and fixtures now in use were installed in January, 1913. Gas-filled lamps of the Mazda C type were put into general use in this building about 1916.

The Moore tube system of lighting was used for a time on the mezzanine floor in 1911. The Cooper-Hewitt system of mercury vapor tubes was used in the basement in 1912. Arc lights were used on the mailing platform in 1914.

SOURCE AND CHARACTER OF THE ELECTRIC CURRENT USED IN LIGHTING.

The electric current used in the City Hall post office building at the present time is direct and is supplied by the New York Edison Co. at 120 volts. It is used for lighting all the offices and corridors in the building and also for running the passenger elevators, the lifts, and the cancellation machines. At the present time about 2,400 kilowatt-hours are used every 24 hours. For all ceiling lights 75, 100, or 200 watt gas-filled Mazda C lamps are used, the 200-watt lamps being used on the mailing platform and in the main floor corridors.

THE MEZZANINE FLOOR (SEE PLAN 1).

The mezzanine floor surrounds the central court, or well, and forms a gallery about 58 feet wide on the east and west sides and 70 feet wide on the north side. The very small amount of daylight present on this floor comes, on the outside, from the semicircular tops of the windows of the first floor, which extend on the mezzanine floor about halfway from the floor to the ceiling, and on the inside, from the very dirty glass roof, or skylight, covering the central court or well. This daylight, producing a natural illumination of the order of only a tenth of a foot-candle, is negligible in comparison with the artificial illumination.

The ceiling of the mezzanine floor is 13 feet 8 inches high. The walls and ceiling were originally cream-colored, but are now very dirty.[1] Their coefficient of reflection was found to be 30 per cent.

[1] All statements made in this report refer to the conditions prevailing at the time of the survey. In some cases conditions have been improved since that time, new lights having been installed or the post office having been repainted.

The eastern portion of this floor is occupied by the separation cases and tables of the dispatching division, the western portion by those of the registry division, and the northern portion by the rest room, the cafeteria, the locker room, the directory service, and the toilet rooms. The approximate locations of the areas occupied by these divisions of the work are shown on plan 1, each area having been given a number shown within a circle. Near the number of the area is given, without a circle around it, the mean value in foot-candles of the artificial illumination within the area. The same information, with the addition of the range of the illumination over any given area, and the number of observations in that area, is given in Table V.

TABLE V.—*Artificial illumination, mezzanine floor, City Hall post office.*

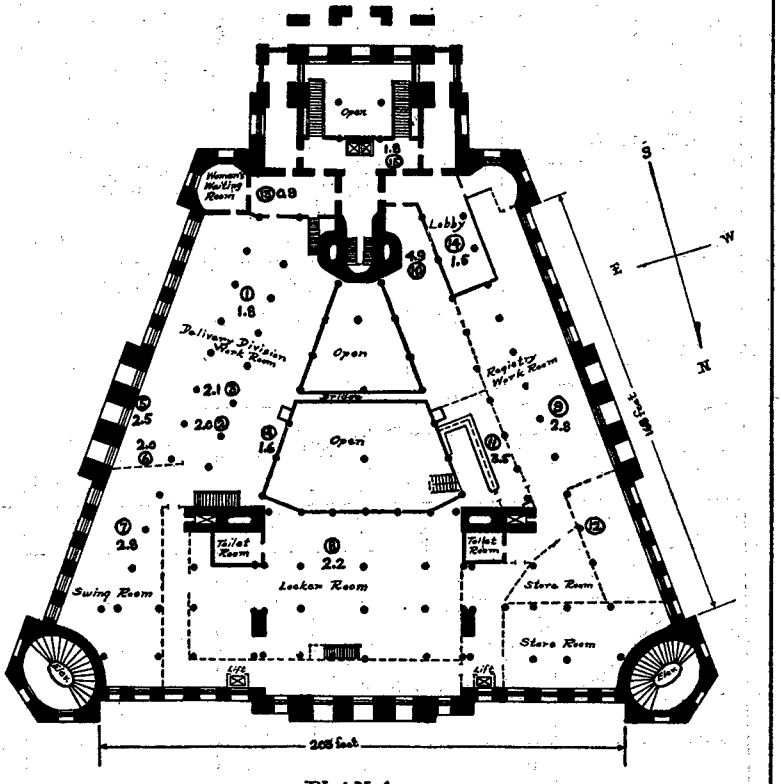
Number of area on plan 1.	Area illuminated.	Range in foot-candles.	Number of observations.	Mean in foot-candles.
1	Letter separation cases	1.0– 4.4	64	1.8
2	Facing tables	1.3– 2.9	17	2.0
3	Cancellation machines	1.4– 3.1	6	2.1
4	Tying-up tables	1.1– 2.4	6	1.6
5	Hospital table	2.5	1	2.5
6	Timekeeper's desk	2.0	1	2.0
7	Rest room	2.0– 4.1	3	2.8
8	Locker room	1.6– 2.9	2	2.2
9	Registry division	1.4– 5.3	12	2.8
10	do	.8–13.7	4	4.9
11	do	3.2– 3.9	3	3.5
12	Directory searching	1.1–30.3	10	9.0
13	Watchman's room	.6– 1.6	3	.9
14	Lobby, registry division	1.2– 1.7	2	1.5
15	Stairway lobby	1.8	1	1.8
			135	2.6

Dispatching division (area 1, plan 1).

The letter separation cases of the dispatching division are arranged in five aisles running NNE. and SSW. on the mezzanine floor. The aisles have the following widths (over-all width from shelf to shelf): No. 1, 5 feet; No. 2, 4 feet 9 inches; No. 3, 8 feet 3 inches; No. 4, 6 feet 6 inches; No. 5, 6 feet 4 inches. Their lengths are, respectively, 77, 78, 78, 53, and 56 feet. The lamps of the ceiling lights on this floor are at a distance of about 3 feet from the ceiling and 10 feet 8 inches above the floor. They are supplied with deep bowl, direct-lighting reflectors, of medium-intensity opal glass, made for 150-watt lamps. In the southeastern portion of the mezzanine floor, containing the separation cases, tying-up tables, facing-up tables, cancellation machines, and timekeeper's desk, there are 55 lamps, 47 of 100 watts, and 8 of 75 watts. The spacings of the lamps in the rows and the distances between the rows are irregular. There are seven rows of lamps, and the lamps are, on an average, 13.6

feet apart in the rows. The distances between the rows, beginning on the east side, are 8, 10, 6, 9, 6, and 6 feet, respectively. The lights are irregularly staggered, so that in general the lights of the different rows do not come opposite each other.

Readings of the artificial illumination on the working plane in front of the separation cases are plotted in Figure 1. They were



PLAN 1.
MEZZANINE FLOOR
NEW YORK CITY HALL POST OFFICE

taken 9 inches away from the face of the pigeonholes, on a horizontal plane 45 inches above the floor. The positions of the lamps in each aisle are shown in the figure.

It will be observed that the illumination varied from 1.1 to 4.4 foot-candles and that the mean was 1.8 foot-candles. Its distribution was very irregular, and in 47 out of the 64 values obtained was

below 2 foot-candles. Wherever it was possible, readings were taken 8 feet apart along both sides of the aisles. Every effort was made

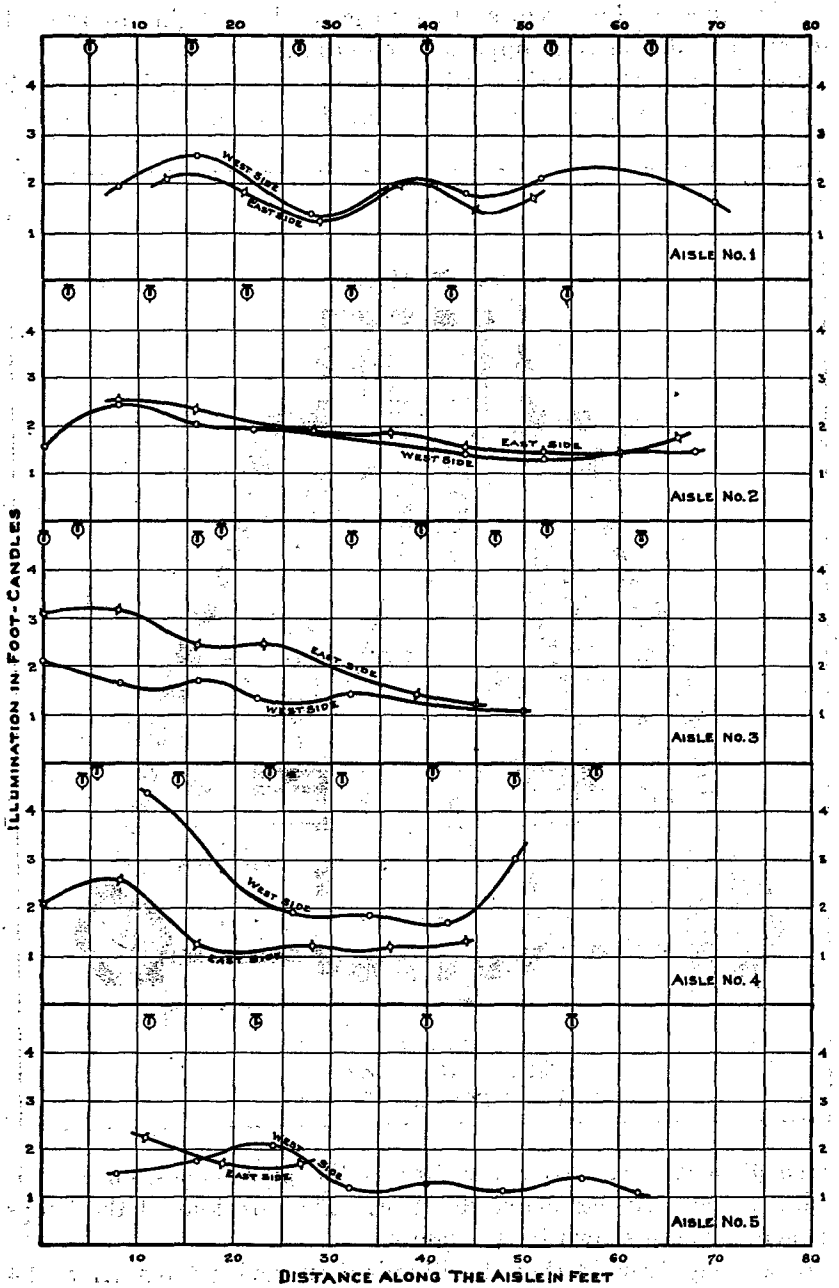


FIG. 1.—Illumination on the horizontal working plane of the separation cases on the mezzanine floor of the New York City Hall post office

to avoid shadows on the test plate, but these were very numerous and difficult to avoid.

To determine how the illumination of the face of the pigeonholes varied from the shelf to the top of the case, the illumination on the face of case 66 was measured. The results are given in Table VI.

TABLE VI.—*Illumination on the vertical face of a letter separation case.*

Number of row.	Distance above shelf (in inches).	Illumination in foot-candles.	Number of row.	Distance above shelf (in inches).	Illumination in foot-candles.
1	4.0	0.82	6	27.5	1.02
2	8.4	.77	7	32.1	1.10
3	13.2	.78	8	36.8	1.25
4	17.9	.89	9	41.5	1.37
5	22.7	.95			

The portion of the mezzanine floor occupied by the letter separation cases, tying-up tables, facing-up tables, and cancellation machines covers about 6,200 square feet. In this area there are forty-seven 100-watt and eight 75-watt lamps, or about 0.85 watt per square foot. Taking the lumen output as 865 lumens for a 75-watt and 1,260 for a 100-watt lamp, 10.7 lumens per square foot [2] were calculated. Since the mean illumination over this area was 1.94 foot-candles, the coefficient of utilization [2] for this area was about 18 per cent.

Registry division (areas 9–11, plan 1).

The registry division occupies the greater part of the western portion of the mezzanine floor. Its greatest length is about 156 feet, its width about 58 feet, and its floor space, therefore, about 7,200 square feet. As already stated, the amount of natural illumination supplied by the half windows and skylight is very small, and on the greater part of the floor the illumination is mostly artificial.

The general artificial illumination is supplied by fifty-three 100-watt and seven 75-watt gas-filled lamps, 60 in all, with deep bowl, direct-lighting reflectors, of medium density opal glass, made for 150-watt lamps, placed at a distance of 3 feet from the ceiling and 10 feet 8 inches above the floor. They are arranged in eight rows running NNW. to SSE., the rows being from 6 to 7½ feet apart. The lamps are, on an average, about 12 feet apart in the rows. The walls and ceiling were originally cream-colored, but are now very dirty.

The floor space of the registry division is divided into four parts by metal screens or wooden cases. There is a large room, where the opening and pouching work is done, and three smaller rooms.

[2] The coefficient of utilization of an illumination installation is the ratio of the total quantity of light falling on the working plane to the total quantity of light emitted by the electric lamps or other primary sources of light.

The opening and pouching room occupies the major portion of the floor space of the division. The center of the room is occupied by 18 large opening and carding tables, each about 40 inches high. Around the sides of the room are arranged counters and separation cases. Readings of the illumination were taken on the horizontal surface of the tables for 12 typical positions throughout the room. To find the average illumination on the separation cases, measurements were taken on three of them. The mean general illumination in the opening and pouching room was found to be 2.8 foot-candles.

From the floor space occupied by this division, the number and wattage of the lamps used to produce the general illumination, and the illumination produced by them, it was figured that there are 0.81 watt per square foot of floor area, and that the coefficient of utilization is about 28 per cent.

It will be noted that the coefficient of utilization is much higher for the registry division than it is for the dispatching division. This may be due to the fact that in the dispatching division the upright portions of the separation cases are nearly 7 feet high and cut off much of the light from the working plane, whereas in the registry division flat tables are used that do not interrupt the light.

Directory service room (area 12, plan 1).

In the directory service room there are five rows of desks and two small separation cases. The surfaces of the desks make an angle of about 20° with the horizontal. The desks are illuminated principally by droplights with green-glass shades placed about 18 inches above them. The values of the illumination, given in Table VII for each row, directly under a light and between two lights, show how very uneven it is, possibly on account of uneven spacing and the type of shades used.

TABLE VII.—*Illumination under the desk lamps of the directory service room.*

Number of row.	Illumination in foot-candles.		Number of row.	Illumination in foot-candles.	
	Directly under a light.	Between two lights.		Directly under a light.	Between two lights.
1	17.4	1.06	4	15.3	3.77
2	15.1	4.18	5	11.2	6.03
3	30.3	3.03			

FIRST FLOOR (SEE PLAN 2).

The first floor is occupied by the delivery division, the superintendent's, weighing, and transportation offices, the stamp and delivery

windows, and the public lobbies. Outside the building, on the north, is the mailing platform, where mail is received and loaded on mail trucks. The central portion of the first floor is covered by the skylight already referred to. The mean illuminations on this floor, both artificial and natural, for its various areas, are shown in Table VIII and on plan 2.

TABLE VIII.—*Illumination, first floor, City Hall post office.*

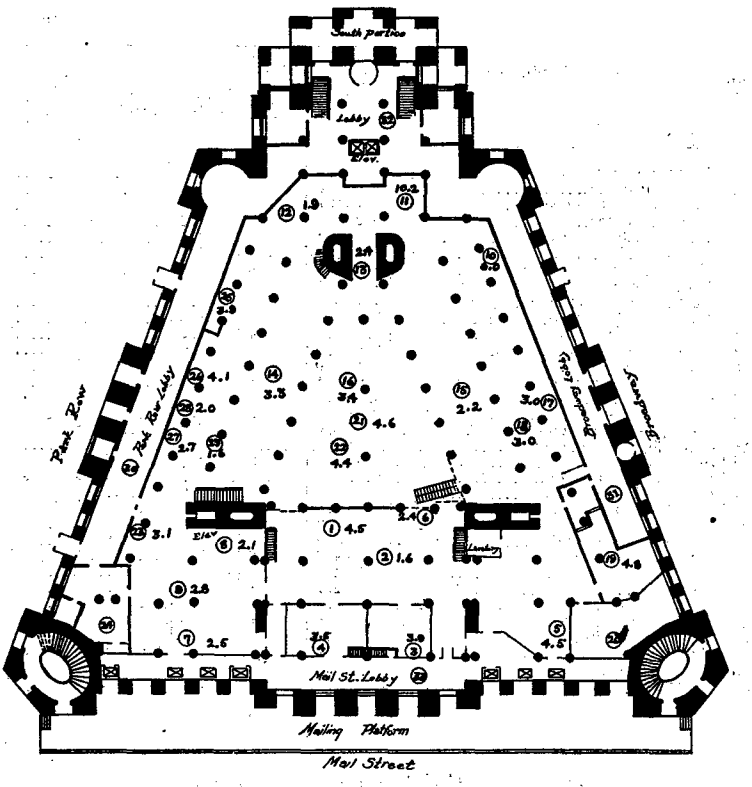
Number of area on plan 2.	Area illuminated.	Artificial.			Natural.		
		Range in foot-candles.	Number of observations.	Mean in foot-candles.	Range in foot-candles.	Number of observations.	Mean in foot-candles.
1	Letter pouching cases	4.2- 5.0	3	4.5			
2	Pouching racks	1.6	2	1.6			
3	Transportation office	2.7- 5.6	4	3.9			
4	Weighing office	2.2- 4.4	5	3.5			
5	Facing tables for circulars	1.1- 9.1	3	4.5			
6	Opening table	2.4	1	2.4			
7	Newspaper separation case	1.3- 4.1	6	2.5			
8	Large newspaper separation case	1.6- 2.7	6	2.1			
9	Facing and cancellation tables	1.7- 4.4	10	2.8			
10	Box delivery section	4.8- 7.2	2	6.0			
11	Redirecting section	2.8-19.0	4	10.2			
12	General delivery section	0.8- 3.9	9	1.9			
13	Unpaid section	0.1- 4.9	5	2.4			
14	Letter separation cases	2.0- 5.1	26	3.3			
15	Carriers' separation cases	1.1- 3.7	32	2.2	0.6	1	0.6
16	Facing tables	2.4- 4.4	2	3.4			
17	Facing table and window	2.6- 3.6	3	3.0			
18	Cancellation machines			3.0			
19	Stamp office	1.3-10.0	3	4.8	4.2	1	4.2
20	Special delivery room				4.1- 5.8	2	5.0
21	Cancellation table	4.6	1	4.6			
22	Opening table	4.1- 4.6	3	4.4			
23	Parcel-post receiving window	2.1- 4.3	3	3.1			
24	Superintendent's office	5.5-38.0	9	14.2	1.0-208.0		
25	Receiving windows	3.1- 4.6	2	3.9			
26	Bank mail window	3.1- 4.6	3	4.1			
27	Call boxes	2.7	1	2.7			
28	Letter separation case	2.0	1	2.0			
29	Parcels separation case	1.6	1	1.6			
30	Park Row lobby				2.3- 20.0	2	11.2
31	Broadway lobby				33.0-230.0	2	132.2
32	Entrance lobby				1.0	1	1.0
33	Mail platform lobby				6.3- 15.4	6	12.4
			150	3.8			

Delivery division (*area 14, plan 2*).

There are two kinds of letter separation cases in the delivery division, those used by the mail clerks and those used by the carriers. To distinguish them, they may be called separation cases and carriers' cases, respectively.

The separation cases are similar to those used on the mezzanine floor in the dispatching division and are arranged in four aisles, varying in width from 3 feet 9 inches to 5 feet 2 inches. Aisles 1, 2, and 3 are entirely under the mezzanine floor, while aisle 4 is under the skylight. Aisles 1, 2, and 3 are illuminated almost entirely by artificial light, and aisle 4 by both artificial and natural light. The lights illuminating the aisles consist of 75 or 100 watt

gas-filled lamps, with open holophane reflectors, arranged in rows parallel to the aisles. The lights are distributed somewhat irregularly and are usually placed about 1 foot from the ceiling, which is 13 feet 9 inches high. They are, on an average, about 11 feet apart in the rows which are about 5 feet apart. Figure 2 gives the in-



PLAN 2.
FIRST FLOOR
NEW YORK CITY HALL POST OFFICE

tensity of illumination in foot-candles along each aisle on a horizontal plane 45 inches above the floor and 9 inches in front of the face of the pigeonholes. It will be noted that the total illumination varied from 2 to 11.8 foot-candles. The mean artificial illumination on these cases was 3.3 foot-candles.

The carriers' separation cases occupy the greater part of the southwest portion of the first floor (area 15, plan 2). They are similar

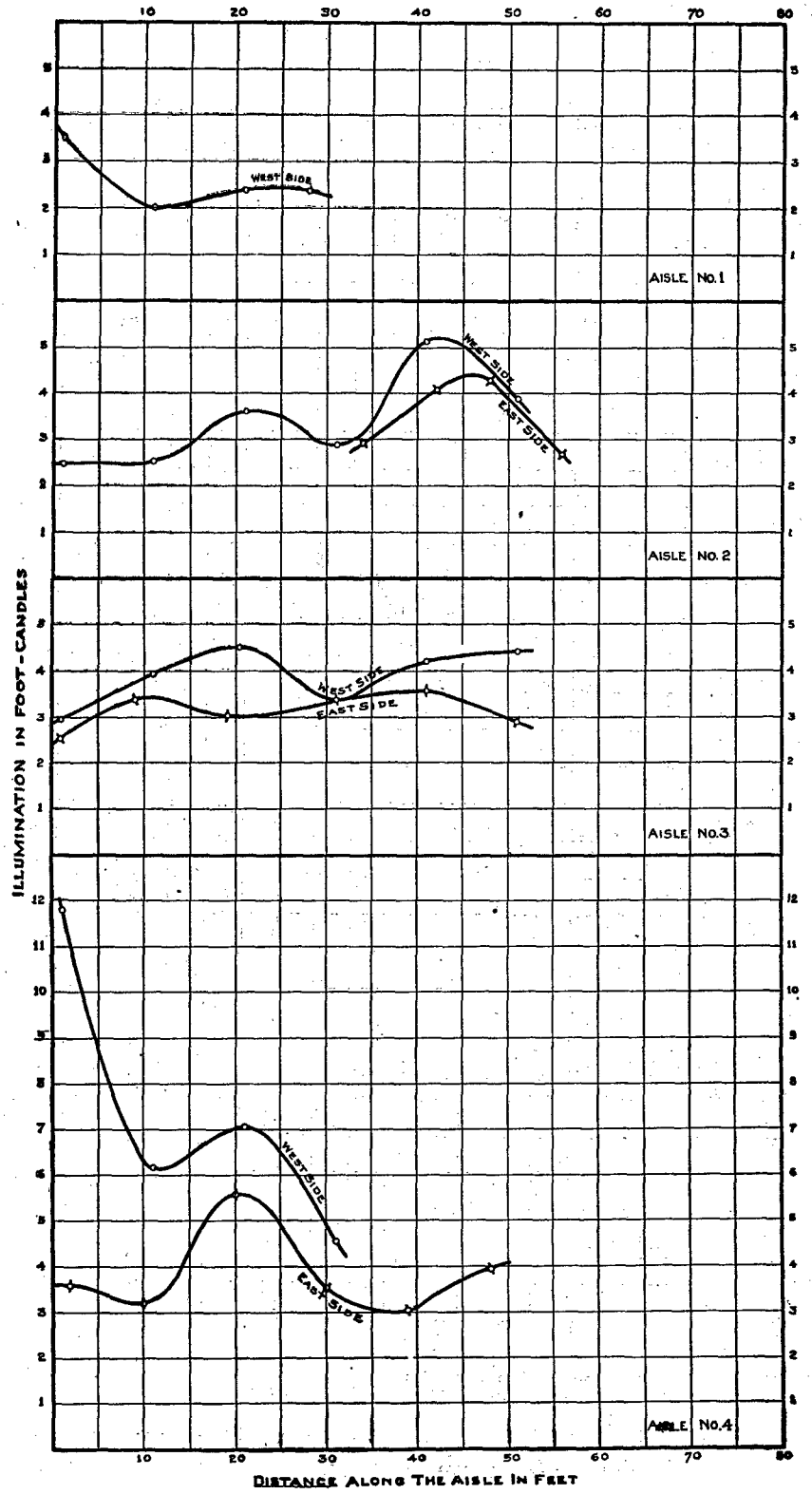


FIG. 2.—Illumination on the horizontal working plane of the separation cases on the first floor of the New York City Hall post office

to the other separation cases on the first and mezzanine floors. They are 6 feet high and have each a shelf 22 inches wide, projecting in

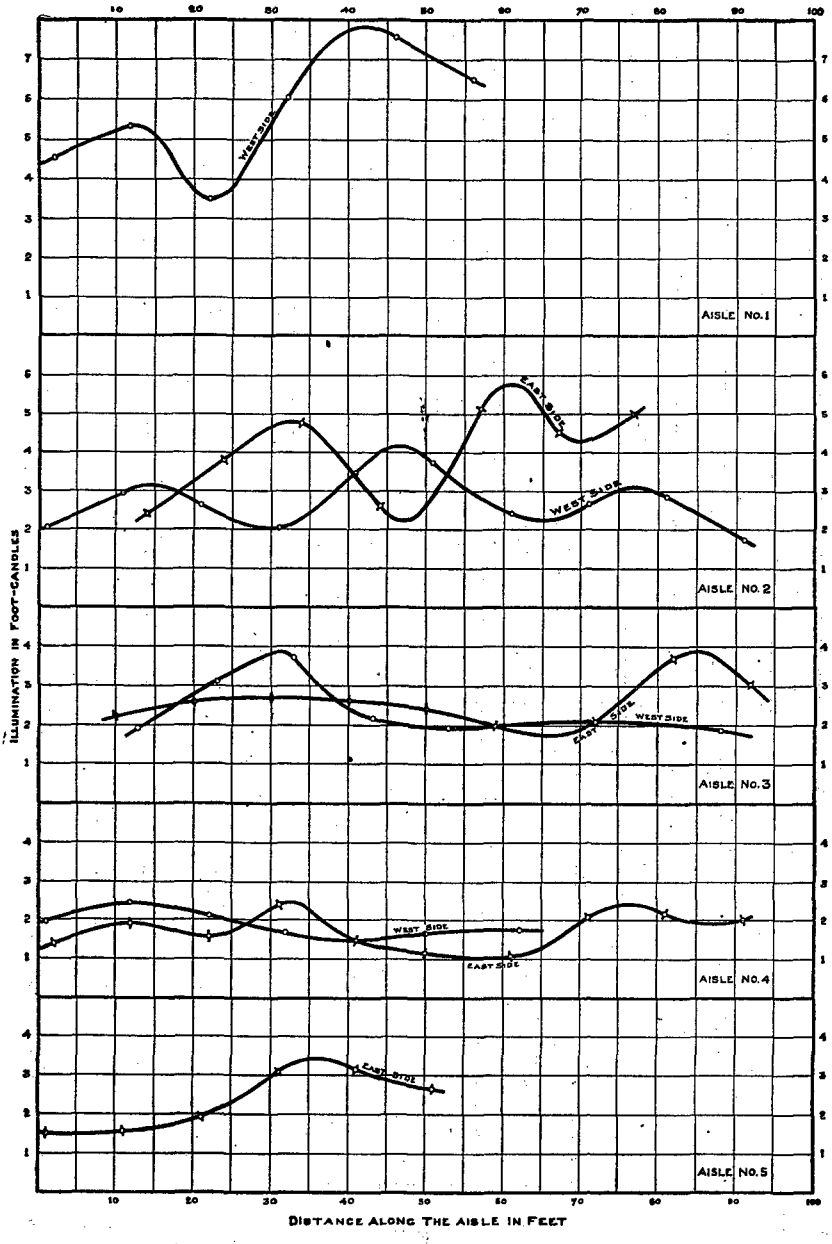


FIG. 3.—Illumination on the horizontal working plane of the carriers' cases on the first floor of the New York City Hall post office

front at a height of 34 inches above the floor. There are six horizontal rows of pigeonholes above the shelf, and as many of these are

used as are necessary. The cases are arranged in five aisles, from 54 to 96 feet long, and 6 feet 9 inches wide.

As in the letter-separation cases, the lights illuminating these aisles are 75 or 100 watt gas-filled lamps, with open holophane reflectors, placed about 1 foot from the ceiling and arranged rather irregularly in rows parallel to the aisles. There are two rows of lights in each aisle. On an average the lights are 16 feet apart in the rows and the rows are 7 feet apart. Aisles 3, 4, and 5 are under the mezzanine floor, and their illumination is nearly all artificial; aisles 1 and 2 are under the skylight and are illuminated partly by daylight and partly by artificial light. The measurements of the illumination of the carriers' separation cases on the horizontal plane, at a height of 45 inches from the floor and 9 inches in from the edge of the shelf, are plotted in Figure 3.

The readings plotted in Figure 3 were made during the daytime, so that part of the light producing the illumination is due to daylight coming from the skylight in aisles 1 and 2. In aisles 3, 4, and 5 most of the light—probably 90 per cent of it—is artificial, whereas in aisles 1 and 2 probably only 50 per cent is artificial. This accounts for the much higher illumination in aisles 1 and 2. For this reason the illumination at night is of necessity lower than that shown in the table. The mean illumination for all the carriers' separation cases, as measured during the day, was found to be 2.8 foot-candles. The mean for aisles 3 and 4, alone, where the illumination is practically all artificial, was 2.2 foot-candles.

BASEMENT (SEE PLAN 3).

The basement is given over to the handling of second, third, and fourth class mail; i. e., newspapers, circulars, and parcels.

The processes performed are separation and cancellation. There are two offices for the executive and clerical work involved in these processes, and also toilet rooms, a carpenters' shop, and storerooms.

The basement is lighted entirely by artificial light. The values of the illumination for its different areas are shown in Table IX and on plan 3.

TABLE IX.—*Artificial illumination, basement, City Hall post office.*

Number of area on plan 3.	Area illuminated.	Range in foot-candles.	Number of observations.	Mean in foot-candles.
1	Newspaper jugs (separation cases)	2.9– 4.5	3	3.7
2	Cancellation table	4.5– 5.5	4	4.8
3	.....do	4.5– 6.2	3	5.1
4	.....do	2.2– 2.4	2	2.3
5	.....do	2.9	1	2.9
6	.....do	4.4– 5.6	4	5.0
7	.....do	2.4– 3.3	3	2.9
8	Parcel post separation racks	1.8– 2.2	2	2.0
9	.....do	2.3– 3.1	4	2.8
10	.....do	1.6– 4.2	3	3.1
11	.....do	6.2– 7.3	3	6.9
12	Parcel post distributing case	4.5– 7.0	5	5.8
13	Newspaper section office	2.2–19.8	4	9.8
14	Inquiry office	6.0–12.0	1	8.5
15	Carpenter's shop	1.5–19.4	.....	[1] 10.0
16	Mail-sack storeroom	0.9	1	0.9
17	Cancellation table	3.5	1	3.5
18	Returned-mail table	1.4	1	1.4
19	.....do	2.0	1	2.0
20	Toilet room	0.8– 1.5	3	1.1
21	Stairway	0.3– 0.7	3	0.5
			52	4.2

[1] Not used in taking the mean for whole floor since shop is occupied by one man only who works under droplights.

The lighting units are 100-watt or 75-watt gas-filled lamps, with shallow dome, enameled steel reflectors, placed at a height of about 9 feet 9 inches above the floor. The ceiling of the basement is 16 feet 2 inches high. The bare lamps projecting from their shallow reflectors produce exceedingly bad glare throughout the whole basement.

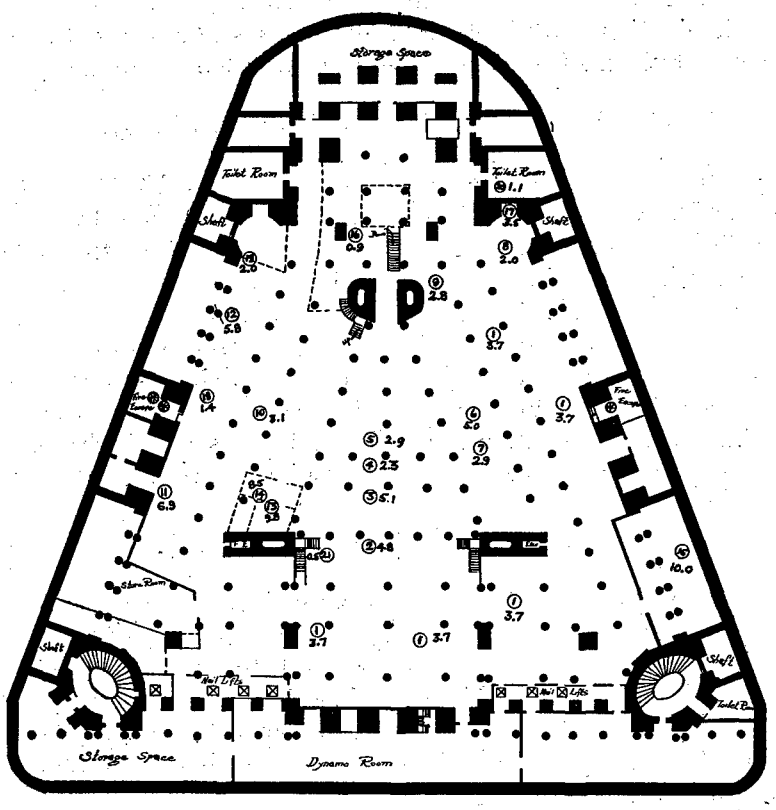
Newspaper separation cases (jugs—area 1, plan 3).

There are five newspaper separation cases, commonly known as "jugs." These are all of the same size and design, and have the same arrangement of lighting units. Therefore the illumination on only one of them, No. 5, was measured.

A "jug" is U-shaped, with a shelf within the U. The clerk stands within the U and throws the mail into the boxes. The shelf is 50 inches wide and 36 inches above the floor. There are 6 boxes, or large pigeonholes, in a vertical row, and 30 in a horizontal row, making 180 boxes in a case. The top of the highest row of pigeonholes is 7 feet 3 inches above the shelf. The boxes are 1 foot high, 1 foot 3½ inches wide, and 3 feet 2 inches deep. The case measures 52 feet 5 inches on the outside and 38 feet 9 inches on the inside. The opening of the U on the inside is 9 feet 9 inches and on the outside 22 feet 2 inches. The case is illuminated by two 100-watt and two 75-watt lamps. These lights are placed symmetrically with respect

to the case 7 feet 6 inches above the table, 3 feet in front of the boxes, and at a distance of 6 feet 8 inches from each other.

Readings of the illumination taken on the shelf 1 foot from the edge on each of its three sides gave 2.84, 4.22, and 3.38 with a mean of 3.48 foot-candles. Taken at 45 inches above the floor, the same posi-



PLAN 3.
BASEMENT
NEW YORK CITY HALL POST OFFICE

tions gave 2.87, 4.52, and 3.72, with a mean of 3.72 foot-candles. An examination was made of the illumination on the vertical face of the case on each of its three sides. The illumination was taken at the top of each row. The results are given in Table X.

TABLE X.—*Illumination on the vertical face of a newspaper separation case.*

Number of row.	Distance above the table (in inches).	Illumination in foot-candles.			Number of row.	Distance above the table (in inches).	Illumination in foot-candles.		
		North side.	West side.	South side.			North side.	West side.	South side.
1	20	2.28	2.89	2.63	4	58	3.37	5.57	3.50
2	33	2.64	3.85	2.98	5	70	3.17	5.30	3.41
3	45	3.06	4.23	3.17	6	84	1.75	3.63	2.38

After the mail has been separated, the contents of each box are transferred to a pouch by opening the box at the back of the case. The illumination at the back of one of the cases on a horizontal plane 45 inches from the floor, was found to be 3.03 foot-candles.

Parcel post separation case (area 12, plan 3).

The parcel post separation case is formed by a table 14 feet long, 8 feet wide, and 3 feet high, surrounded on three sides by wooden bins. The parcels to be separated are transferred from the table to the bins, which are about 5 feet from it. The case is illuminated by six 100-watt lamps. Measurements of illumination were made in the working area of the case—that is, between the table and the bins—on a horizontal plane, at a height of 45 inches above the floor. Five measurements taken around the table gave a mean of 5.80 foot-candles. The illumination for this case is unusually high, but the glare is very bad, on account of the bare lamps in the shallow dome reflectors.

Separation racks (areas 8–11, plan 3).

The parcels for distribution are separated into pouches supported by iron racks about 40 inches high. The clerk stands while separating, and transfers the parcels from a tub to a pouch, usually by throwing them. Four distinct areas in the basement are occupied by these pouching racks. Readings taken on a horizontal plane 45 inches above the floor gave illuminations varying from 1.8 to 7.3 foot-candles.

SECOND FLOOR.

Money-order office.

The natural illumination in the money-order office is unusually good. During the daytime this office is lighted by five large windows facing north on City Hall Square. It is open only from 9 a. m. to 5 p. m. In the office itself there are 10 ceiling lights with 75-watt or 100-watt gas-filled lamps, 10 feet above the floor. The illumination of a writing desk by a window by daylight on January 21, at 10.50 a. m.,

with a cloudy sky and while it was raining, was 28.3 foot-candles. On a writing desk near a window and under a lamp it was 16.3 foot-candles.

The counters at the public windows are illuminated by droplights, with green glass shades and 50-watt lamps. The mean artificial illumination on the counters was 11.3 foot-candles.

In the public lobby of this office, with 10 ceiling lights with gas-filled lamps, the mean artificial illumination on the tables was 3.2 foot-candles.

Cashier's office.

The cashier's office is open from 8 a. m. to 5 p. m. The natural illumination of this office is poor. The main office is illuminated by two high windows, facing east southeast, and two ceiling lights with 75-watt gas-filled lamps, 9 feet 6 inches above the floor. The window counters are illuminated by bracket lamps with holophane reflectors. Illumination on the window counters at 11.25 a. m. was found to be 4.33 foot-candles. In the public lobby of this office the mean artificial illumination was 2 foot-candles; on a desk under a lamp it was 8.4 foot-candles.

Corridors.

In the east corridor the mean artificial illumination was 0.4 foot-candle, and in the west corridor, 0.3 foot-candle.

SUMMARY OF THE ILLUMINATION IN CITY HALL POST OFFICE.

The mean illumination for the principal floors of the City Hall post office and the weighted mean for the whole post office are given in Table XI. The mean for the second floor is not given, because only a few clerks work on this floor, and these work mainly under daylight.

TABLE XI.—*Mean artificial and natural illumination of the principal floors of the New York City Hall post office.*

Floor.	Number of observations.	Illumination in foot-candles.	
		Artificial illumination.	Natural illumination.
Mezzanine	135	2.6	[1] 0.1
First	150	3.8	[1] .7
Basement	52	4.2	None.

[1] Estimated.

The mean artificial illumination of the City Hall post office is 3.4 foot-candles.

ILLUMINATION OF THE NEW YORK GENERAL POST OFFICE.

SHAPE AND CHARACTER OF THE BUILDING.

The general post office in New York City is bounded by Eighth Avenue, Thirty-first and Thirty-third Streets, and an open space to the west. The building is rectangular in shape, four stories high, with a basement, and is built around an open court, the first floor of which is covered by a glass roof, or skylight. The total length of the building, north and south, on Eighth Avenue, is 376 feet, and east and west, on Thirty-first Street, it is 335 feet. The dimensions of the court are 224 feet from north to south and 155 feet from east to west. Floor plans of this building are marked plans 4 and 5.

HISTORY OF THE BUILDING AND OF THE LIGHTING.

The building was not completed until the summer of 1914, although portions of it were occupied before that time.

The west part of the basement, the weighing office, and the transportation platform and office were occupied in November, 1910, and were lighted at that time by Cooper-Hewitt mercury vapor lamps in the basement, flaming arc lamps on the mailing platform, and the present fixtures in the weighing and transportation offices. In 1912 the Cooper-Hewitt lamps, and in 1913 the flaming arc lamps, were removed and were replaced by the units now present.

The other departments moved into the building during the years 1913, 1914, and 1915.

Indirect lighting was originally installed in the dispatching division on the first floor, but on account of insufficient illumination was changed in 1915 to the present system of direct lighting with holophane reflectors. In the same year the local lights now in use were installed over the separation cases in the dispatching and delivery divisions on the first floor.

In 1917 the fixtures in the registry division were lowered from 12 feet to 10 feet above the floor, and later the holophane reflectors in that division were replaced with the conical painted steel reflectors now in use. These fixtures are now being restored to their original height, and Ivanhoe Regent Sudan reflectors are being substituted for the steel reflectors.

In 1919 the fixtures in the money-order workroom on the third floor were lowered from 10 feet 6 inches to 8 feet 6 inches above the floor, but have recently been restored to their original height. In 1920, 32 two-light fixtures were installed in this room to replace the same number of one-light fixtures.

SOURCE AND CHARACTER OF THE ELECTRIC CURRENT USED IN LIGHTING.

Direct current at 120 volts is used on the lighting circuits in this building at the present time, and is supplied by the New York Edison

Co. About 3,000 kilowatt hours are used in every 24 hours. For ceiling lights, 75, 100, or 200 watt gas-filled lamps are used.

FIRST FLOOR (SEE PLAN 4).

The main working room on the first floor is, except for a few small offices, an open area roughly 350 feet wide by 200 feet deep, covered in its central portion by a skylight. It is occupied by the dispatching and delivery divisions and is divided into areas in which are separation cases, sorting racks, and opening-up tables. In Table XII is given the mean illumination, both artificial and natural, for each area, with its range, and the number of observations. The location of each area is shown on plan 4 by a number within a circle, and the mean artificial illumination, within the area, by a number outside the circle. The illumination was always measured on the horizontal working plane, on a table or desk, or else at a height of 45 inches above the floor.

TABLE XII.—*Illumination, first floor, general post office.*

Number of area on plan 4.	Area illuminated.	Artificial.			Natural.		
		Range in foot-candles.	Number of observations.	Mean in foot-candles.	Range in foot-candles.	Number of observations.	Mean in foot-candles.
1-a	Parcel post tables	3.1–4.9	10	3.8	2.3– 7.7	13	4.6
1-b	Parcel post racks				12.9–32.0	3	25.0
2	Letter separation cases (dispatching division)	1.8–7.8	124	3.6	.9–91.2	10	26.4
3	Facing tables and cancellation machines	1.8–3.5	11	2.4	1.8–27.2	4	8.3
4	Newspaper jugs	2.4–3.4	6	3.0			
5	Parcel post racks			2.9			
6	Newspaper separation cases	2.8–4.1	3	3.3			
7	Wholesale stamp office	3.3	1	3.3			
8	Letter separation cases (delivery division)	2.7–4.8	15	3.6	5.1– 5.9	4	5.5
9	Newspaper route cases	4.2–6.0	3	4.7			
10	Opening form, dispatching division	3.3–4.3	4	3.8			
11	Opening form, delivery division	1.4	1	1.4			
12	Pouching racks	1.7–3.0	5	2.3			
13	Opening table, foreign section	2.0–3.4	4	2.6	2.6–40.0	2	21.3
14	Mailing inspection	2.6	1	2.6			
15	Parcel post racks			2.3			
16	Mail carriers' cases	2.8–6.2	15	4.3			
17	Parcel post tables	2.7–3.0	3	2.9	4.3–27.5	24	11.6
18	Letter route cases	2.3–2.6	3	2.5			
19	Opening-up table	1.6–2.6	3	2.1			
20	Parcel post racks	2.2–3.8	4	3.1			
21	Facing and cancellation tables	2.6–4.0	4	3.3			
22	Short paid table	8.9	1	8.9	30.0	1	30.0
23	Facing table, moving belt	1.0–2.4	5	1.6			
24	Transportation office	2.5–6.1	6	4.9	1.4–57.0	3	26.1
25	Mailing platform, lobby	1.6–2.2	2	1.9	9.5–10.6	2	10.0
26	Weighing room	3.6–8.1	3	5.4	1.0	1	1.0
27	Office assistant superintendent, dispatching division	5.3–6.2	2	5.8	1.0– 4.2	3	2.3
28	Office assistant superintendent, delivery division	3.6	1	3.6			
29	Money-order window	9.6	1	9.6	3.4–40.0	2	21.7
30	Paying cage	5.0	1	5.0			
31	Mailing platform	3.0	1	3.0			
			243	3.6		72	13.3

Natural illumination is supplied in its central portion by the skylight, and on the north, south, and east sides by the outside windows.

The general artificial illumination on the first floor is supplied, under the ceiling, by 75-watt gas-filled lamps with open holophane reflectors, the fixtures being 13 feet 8 inches apart, and carrying two lamps, 2 feet apart and 15 feet above the floor. Under the skylight 200-watt lamps are used, one lamp to an outlet, 16 to 18 feet apart and 20 or 31 feet above the floor. In addition to the ceiling lights, the letter-separation cases are lighted by bracket lights, with 15-watt lamps and metal reflectors, placed about 4 feet above the shelf, about 14 inches in front of the face of the pigeonholes and from 2 to 3 feet apart. About half the cases are of the same type as those used in the City Hall post office, and the rest are wing-shaped; that is, with a central portion facing the clerk and with side wings inclined toward him so as to decrease the distance to the pigeonholes. The work performed and the illumination required are essentially the same for both types of cases.

It will be observed from Table XII that the mean artificial illumination for the whole floor was 3.6 foot-candles, and that the mean natural illumination was 13.3 foot-candles. The natural illumination was measured at different times during the day under average conditions of cloudiness, and the values given may be considered average values.

The separation cases on the first floor, under the mezzanine floor and farthest away from the windows, but not under the skylight, are illuminated by artificial light all the time. Those near the windows and those under the skylight have sufficient natural light during the daytime.

On this floor there are overhead conveyors, mechanical devices for transporting mail from one portion of the floor to another, which frequently interfere with the overhead illumination and cast shadows upon the working planes. A very bad case is that of the facing-up table with a moving belt, shown as area 23 on plan 4. Here the working plane was lighted by bare lamps 3 feet above it, producing very bad glare, and the illumination was only 1.6 foot-candles.

Since open reflectors with 75, 100, or 200 watt lamps are used for general illumination on this floor, there is everywhere more or less glare from the exposed filaments of the lamps. This is particularly marked in the case of the newspaper separation cases or jugs, shown as area 4 on plan 4, since the lights above these cases are so placed that the clerks, when throwing packages into the upper tiers of boxes, face directly the bare filaments of the 200-watt lamps. Another instance was that of the separation case used as an opening form (area 10, plan 4). Here again the clerks, when throwing the

mail into the boxes, face the bare lamps directly. At the small opening form near by (area 11, plan 4) there was similar glare and, in addition, very low illumination—only 1.4 foot-candles.

In the foreign section (area 13, plan 4), where the work is particularly hard on the eyes because the marks on the foreign stamps and the foreign writing are hard to read, the illumination was only 2.6 foot-candles.

In the money-order office (area 29, plan 4) the bracket lamps at the public windows are so placed that they produce very bad glare in the eyes of the clerks stationed at these windows.

The public corridors and lobbies are on the Eighth Avenue side of the first floor, and are illuminated during the daytime by the windows and doors on that side, and at night by ceiling lights.

BASEMENT (SEE PLAN 5).

The basement, shown in plan 5, is occupied by separation cases, separation tables, and pouching racks of the dispatching division and the Railway Mail Service, those of the former occupying the northern and those of the latter the southern portion of the floor. The central portion of the basement is illuminated entirely by artificial light, but on the north and south sides daylight enters from the basement windows. This light extends only to the first row of pillars, about 40 feet; beyond these it is necessary to use artificial light all the time.

The general artificial lighting in the basement is supplied by 75 or 100 watt gas-filled lamps with holoplane reflectors, hung from 10 to 12 feet above the floor and about 12 feet apart. Since the reflectors are open and the lamps are bare, they produce much glare. The letter separation cases are supplied with increased local illumination by bracket lamps over the tops of the cases.

All over the basement there are overhead conveyors, carrying the mail mechanically from one part of the basement to another or from the basement to the mailing platform and the trains. These conveyors seriously interfere with the overhead lighting by casting shadows on the racks and tables and make it difficult to place the lights satisfactorily.

The location of the areas occupied by the different classes of work with the mean illumination within the areas, is shown on plan 5. The range and the mean value of both the artificial and the natural illumination in these areas are also given in Table XIII. It will be seen from the column containing the range that the artificial illumination lacks uniformity; for instance, it varies in area 16, which contains pouching racks, from 1.3 to 7.6 foot-candles. The mean artificial illumination in the basement was 3.3 foot-candles, and the mean natural illumination near the windows, 12.9 foot-candles.

TABLE XIII.—*Illumination, basement, general post office.*

Number of area on plan 5.	Area illuminated.	Artificial.			Natural.		
		Range in foot-candles.	Number of observations.	Mean in foot-candles.	Range in foot-candles.	Number of observations.	Mean in foot-candles.
1	Newspaper jug	1.7- 2.9	5	2.3			
2	do	3.4- 4.6	7	3.9			
3	do	2.4- 3.2	5	2.9			
4	do	2.5- 3.6	5	2.9	2.6- 5.4	2	4.0
5	Parcel post tables and racks	1.0- 7.0	12	3.1	12.8-38.4	2	25.6
6	Letter separation cases	3.9- 7.4	11	5.2	2.7-40.0	2	21.4
7	Separation cases for circulars	2.5- 4.6	3	3.4			
8	do	3.6- 4.1	3	3.9			
9	do	6.7	1	6.7			
10	Cancellation table	1.5- 2.2	4	1.9			
11	Dispatching room	1.1- 2.4	5	1.6			
12	Pouching racks	2.1- 2.8	3	2.3			
13	do	2.3- 6.0	3	4.1			
14	do	2.5	1	2.5			
15	do	3.3-11.0	5	6.7			
16	do	1.3- 7.6	9	3.2			
17	do	2.9- 3.2	4	3.1			
18	do	1.3- 8.2	4	4.8	6.4- 8.9	3	7.2
19	Machine shop	7.6-12.5	3	[1] 10.0			
20	Mail-sack storeroom	.6- 1.5	4	.9			
21	Corridor	.2- 2.4	2	1.3			
22	Parcel post racks			2.5			
23	Toilet room	.2- 2.2	2	1.2			
24	Carpenter's shop	2.7- 3.2	2	3.0			
25	Engineer's room	2.3	1	2.3			
26	Office of Railway Mail Service	3.5	1	3.5	5.0	1	5.0
			105	3.3		10	12.9

[1] Not used in taking the mean for whole floor since only machinists work in this room under droplights.

A striking illustration of poor illumination is that of the mail-sack storeroom, area 20, where the mean illumination was only 0.9 foot-candle, although the clerks and laborers in this room have to read the labels on the sacks. The glare was also very bad in this room, since bare lamps were used, with no reflectors.

The newspaper jugs or separation cases, areas 1–4 on the plan, are of the same shape as those in the basement of the City Hall post office, one of which has been described in detail. The illumination was measured on a horizontal plane in front of the shelf at a height of 45 inches above the floor. The mean illumination on this plane for all these cases was 3.4 foot-candles. Each jug is lighted by three pairs of 75-watt gas-filled lamps, hung 3 feet in front of the boxes and 12 feet above the floor. The lamps have open holophane reflectors.

Tables XII and XIII bring out several definite and important facts: First, that there is a great variation in the range of artificial illumination, from 0.2 foot-candle to 12.5 foot-candles; second, that the amount of illumination for any special occupation does not seem to be dependent upon the intensity of eye work required by that occupation; for instance, it will be seen from Table XII that in area

21 at the facing-up and cancellation tables, where very little detailed eye work is required, there is a mean illumination of 3.3 foot-candles, while at the letter separation cases, area 2, there is a mean illumination of 3.6 foot-candles; and third, that there seems to be no definite amount of illumination even in the same occupation—for instance, for the letter separation cases, where the range of illumination is from 1.8 foot-candles to 7.8 foot-candles.

SECOND FLOOR.

On the second floor are the registry and inquiry divisions and other offices.

Registry division.

The working room of the registry division occupies the western portion and half of the northern portion of this floor of the quadrangle. The windows of the western portion face east and west, and those of the northern portion, north and south. The room is occupied both by day and by night. The general artificial lighting is supplied by 100-watt lamps with conical steel reflectors painted white on the inside. There are two lights to an outlet, and the outlets are 12 feet apart and 10 feet above the floor. The glare from the bare lamps is very bad, and in many cases the inside surface of the reflectors is rusted, so that the efficiency of the unit is very low. Since the room is lighted by windows on both sides, the natural illumination is in general good, although toward the middle of the room, or where light is cut off by partitions, it may be low. The natural illumination varied from 1.2 to 41.6 foot-candles, with a mean value of 12.4 foot-candles. The illumination was measured on April 11, from 10 a. m. until noon, with a sky overcast with clouds, the sun not shining but producing a strong white light. The artificial illumination in this room varied from 2 to 5.8 foot-candles, with a mean of 4.1 foot-candles.

In some parts of this room bare lamps, without reflectors or shades, are used for local illumination. They produce very bad glare and should not be used.

Inquiry division.

The inquiry division occupies the southern portion of the south side of the quadrangle. Its windows face the south. It is occupied only during the daytime. The natural illumination, measured on April 12 at 3.30 p. m., with a cloudy sky and the sun shining, was 128 foot-candles near the windows, and 14 foot-candles near the wall.

Other offices.

The other offices on this floor are occupied only during the daytime. The illuminations were measured on April 11 during the afternoon from 2 to 4.30 p. m., with a cloudy sky. Measurements were made near the windows and away from the windows near the wall. For the offices on the east side of the quadrangle, with windows facing the east, the illumination varied from 50.5 foot-candles near a window to 7.9 foot-candles away from the windows; for those having windows facing the court, from 55.2 to 2.6 foot-candles. For offices on the south side of the quadrangle, with windows facing the south, the illumination varied from 128 foot-candles to 14.0 foot-candles, and for those with windows facing the court, from 22.1 to 5.1 foot-candles.

THIRD FLOOR.

On this floor are the money-order workroom, the offices of the Railway Mail Service, the offices of the inspectors, and the post-office supplies room.

Money-order workroom.

The money-order workroom is 163 feet long and 66 feet wide and occupies the greater part of the north side of the quadrangle. The room has large windows on the north and south sides but none at its east and west ends. Almost all the work is done in the daytime. About 200 clerks work in this room, only five of whom work at night. The desks are arranged in rows running north and south; each clerk has his own desk, and all face the east. A broad aisle runs down the center of the room, and there are also aisles on the north and south sides. The natural illumination in this room is good. It was measured on the horizontal surfaces of the desks, 30 inches above the floor, on April 8, between 11 a. m. and 1 p. m.

Curves A,[3] B, and C of Figure 4 give longitudinal sections, from east to west, of the illumination, near the south wall, in the middle of the room, and near the north wall, respectively. The positions and the extent of the window openings are shown by the distances marked "W" on the figure. Curves A^1, B^1, and C^1 of Figure 5 give transverse sections of the illumination at the points shown in Figure 4.

The curves of Figure 4 indicate the general distribution of the daylight in this room and show that it has a high fluctuating value near the windows and falls to a low, nearly constant value in the central region. Those of Figure 5 show that the illumination due

[3] Irregularity in this curve at west end is probably due to a partition across this end of the room on its south side.

to the south windows is much stronger than that due to the north windows. They also show that over an area about 30 feet wide in the middle of the room the illumination is less than 10 foot-candles.

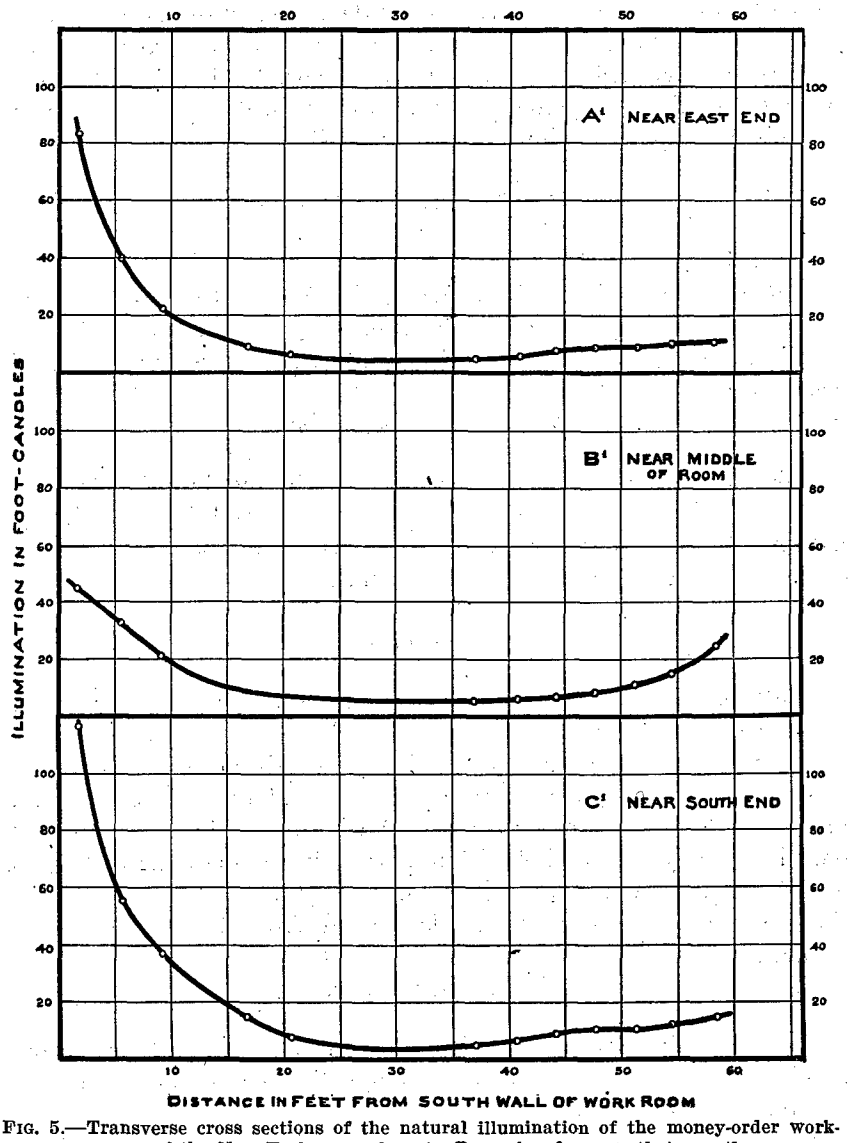


FIG. 5.—Transverse cross sections of the natural illumination of the money-order work-room of the New York general post office going from south to north

The artificial illumination in this room varies from 3.3 to 6.3 foot-candles, the mean being 4.5 foot-candles.

The wiring is poorly arranged in this room. The switches for turning on the lights are placed on a common switchboard, but the

circuits are so arranged that one switch will turn on lights in different parts of the room. Thus, in order to turn on a light that is needed, several that are not needed must be turned on. The circuits should be so arranged in conjunction with the switches that the lights in the middle of the room, which are those first needed and most often used, could be turned on independently of those in other parts of the room, the rows running east and west being turned on successively, each row, or part of a row, by itself. Also, the switches should be arranged on the switchboard in the same order as their corresponding lights, or rows of lights.

Railway Mail Service.

The offices of the Railway Mail Service are on the east side of the quadrangle, with windows facing the east. They are occupied only during the daytime. The mean natural illumination varied on April 12, at 4 p. m., from 12.5 foot-candles near the window to 1.7 near the door.

Post office supply room.

This room occupies the western side of the quadrangle, and has windows facing west and on the court. It has good daylight illumination, 102 foot-candles on April 12, at 4.15 p. m., near a west window. It is used only during the daytime.

FOURTH FLOOR.

The fourth floor is occupied by the registry records room and a number of small offices.

The registry records room occupies the northern and part of the western side of the quadrangle. There are 14 desks in this room, arranged along the north wall by the windows. The room is used only in the daytime, and the illumination on the desks according to measurements taken in the afternoon on April 11, at 4 p. m., when the sky was overcast with clouds, varied from 109 to 10.9 foot-candles.

MEZZANINE FLOOR.

The mezzanine floor is occupied by the money-order records room and by various smaller stock, recreation, and record rooms, which are occupied only during the daytime.

The cashier's stock room, the windows of which face the south, late in the afternoon on April 12, at 4.25 p. m., had an illumination

of 65.6 foot-candles near a window and 4.6 foot-candles near the wall farthest from the window.

Money-order records room.

The money-order records room, on the north side of the building, has 13 desks placed at right angles to the windows, and the illumination on the desks varied on April 10, at 2.50 p. m., from 38.4 to 5.4 foot-candles. The clerks faced the west, and the light came over their right shoulders. It would probably be better if they faced the east. The windows are low, and there is much glare from the light reflected from the opposite buildings and the street below. Opaque green curtains that could be raised from below, so as to cover the lower two-fifths of the window, would eliminate this glare.

SUMMARY OF THE ILLUMINATION OF THE GENERAL POST OFFICE.

In Table XIV are given the mean illumination for each floor of the general post office, and the weighted mean for the whole post office. The fourth and mezzanine floors are omitted, since only a few clerks work on these floors.

TABLE XIV.—*Mean artificial and daylight illumination in foot-candles of the principal floors of the New York general post office.*

Floor.	Artificial.		Natural.	
	Number of observations.	Illumination in foot-candles.	Number of observations.	Illumination in foot-candles.
First	243	3.6	72	13.3
Basement	105	3.3	10	[1] 12.9
Second	14	4.1	43	12.4
Third			138	22.8

[1] Only a small portion of the basement is illuminated by daylight.
The mean artificial illumination of the general post office is 3.5 foot-candles.

COMPARISON OF THE ILLUMINATIONS IN THE TWO POST OFFICES.

In Table XV is given the number of regular employees, not including executives, letter carriers, or employees of the Railway Mail Service, in the two post offices, arranged according to occupational groups, with the average proportion of workday spent under artificial illumination.

TABLE XV.—*Number of employees, proportion of workday spent under artificial illumination, and percentage of those employees whose eyes were examined who work under different amounts of artificial illumination, by occupational groups, in the New York City Hall and general post offices.*

CITY HALL POST OFFICE.

Occupation.	Total workers.[1]		Examined workers (City Hall, 626; general, 1,242).						
	Number.	Average proportion of workday spent under artificial illumination.	Percentage in areas with specified amounts of artificial illumination.						Average artificial illumination in foot-candles.
			Under 1 foot-candle.	1 to 2 foot-candles.	2 to 3 foot-candles.	3 to 4 foot-candles.	4 to 5 foot-candles.	5 foot-candles and over.	
		Per cent.							
Laborers	94	50–100	7.1	0	21.4	42.9	21.4	7.1	3.5
Facers	18	100	0	0	40.0	40.0	20.0	0	3.3
Parcel-post separators	75	100	0	6.7	20.0	40.0	0	33.3	4.2
Newspaper separators	80	100	0	0	22.2	57.4	10.2	10.2	3.7
Clerks	[2] 314	100	0	1.	44.7	21.9	12.1	20.0	3.8
Letter separators	302	100	0	27.3	10.5	53.6	3.0	5.6	3.1
Total	883		.2	12.3	25.0	42.6	7.9	12.0	[3] 3.4

GENERAL POST OFFICE.

Laborers	131	60–100	33.8	4.0	11.3	46.4	3.3	1.3	2.4
Facers	133	60	6.9	31.0	24.1	34.5	3.5	0	2.5
Parcel-post separators	28	60–100	0	2.6	7.7	69.2	17.9	2.6	3.6
Newspaper separators	239	60	.7	.7	27.5	53.0	10.1	8.1	3.5
Clerks	[4] 1,049	60	1.0	1.9	4.2	14.1	63.0	15.8	4.5
Letter separators	696	60	0	.4	3.2	82.9	9.6	3.9	3.7
Total	2,276		4.6	2.0	8.0	56.1	22.4	6.9	[3] 3.7

[1] Regular employees only, also exclusive of executives, mail carriers, or employees of the Railway Mail Service.
[2] Includes a group of 36 clerks in offices using only natural illumination.
[3] Weighted by total number of employees, not number examined, in each occupational group.
[4] Includes a group of 625 clerks in offices using only natural illumination.

In this table there is also given the percentage of those employees whose eyes were examined who work under different degrees of illumination. These percentages were determined by the survey of the illumination described in this section and by an investigation of the character and location of the work performed by each of the employees examined, as explained in the section that follows on eye examinations. It will be noted that in both post offices a greater number of employees work under an average illumination of 3 to 4 foot-candles than under any other average illumination, 56.1 per cent working between these limits in the general post office and 42.6 per cent in the City Hall post office. On the other hand it will be noted that 22.4 per cent work under 4 to 5 foot-candles in the general post office, compared with 7.9 in the City Hall post office; and that 8 per cent work under 2 to 3 foot-candles in the general post office, compared with 25 per cent in the City Hall post office.

The average artificial illumination, obtained in this way, is therefore slightly higher for the general post office than for the City Hall,

being 3.7 foot-candles in the former and 3.4 foot-candles in the latter. The corresponding values given in Tables XI and XIV, obtained from the illumination surveys, are 3.5 and 3.4, respectively, for these two post offices. The means of the values obtained in these two ways were found to be 3.6 foot-candles for the general post office and 3.4 foot-candles for the City Hall post office.

In Table XVa is given the percentage of the employees whose eyes were examined in both post offices who work all the time either under artificial or natural illumination or part of the time under each. It will be noted that at the City Hall post office 87.3 per cent work under artificial illumination all the time, whereas at the general post office only 27.4 per cent do so; also that in the City Hall post office only 3.3 per cent work under natural illumination all the time, whereas at the general post office 29.7 per cent do so.

TABLE XVa.—*Percentage of employees in the New York City Hall and general post offices whose eyes were examined working all of the time under artificial or natural illumination or part of the time under each.*

	Number examined.	Artificial illumination all the time.	Part artificial and part natural illumination.	Natural illumination all the time.
City Hall	709	87.3	9.4	3.3
General	1,740	27.4	42.8	29.7

ILLUMINATION OF OTHER POST OFFICES IN THE VICINITY OF NEW YORK.

In the Trenton post office artificial illumination is used during all the working hours, since the natural illumination is insufficient. It is provided by irregularly spaced 100-watt Mazda C lamps in open holophane reflectors and by local lights on desks and separation cases. A few Ivanhoe Sudan, open, opal-glass reflectors are also used. The general illumination varied from 5 foot-candles directly under a lamp to less than 1 foot-candle at places distant from lamps. Many of the lamps throughout this post office were without shades, and many of the outlets meant for lamps were used for other purposes.

In the Philadelphia post office artificial illumination is used in the general workrooms all the time. The executive offices have natural lighting from large windows. The general artificial illumination in the general workroom is very irregular, varying from 2 to 5 foot-candles. The artificial illumination is supplied by 100-watt or 40-watt Mazda lamps in open, opal-glass reflectors and by local lights on the cases. Many of the lamps had no shades, and many were burned out.

The New Haven post-office building is only 3 years old, and its natural illumination is very good. There are windows on all four sides and a large double skylight overhead. Artificial illumination is needed during only part of the working time. The main floor is used for all post-office work, the basement being used only for locker and swing rooms. The executive offices are along the sides of the building, adjacent to the windows, and the general workroom is under the central area of the skylight. General artificial lighting is supplied by 150-watt Mazda C lamps, in Ivanhoe Sudan reflectors. Local 15-watt lamps with metal reflectors are used on the letter separation cases. Many bare lamps and empty sockets were noted.

In the Hartford post office artificial illumination is used all the time, since the natural illumination is negligible except near the windows. The general artificial illumination is furnished by 100-watt or 40-watt lamps in open holophane or Ivanhoe Sudan reflectors. The lamps are irregularly spaced and the general illumination is low. The average general illumination on the central area of the mezzanine floor was found to be about 1.5 foot-candles, and on the letter separation area on the main floor, less than 1 foot-candle. There are local 15-watt lamps, in metal reflectors, on the letter separation cases. Bare lamps were present in profusion, and a large percentage of the employees wore eye shades.

IV. EYE EXAMINATIONS.

EYE WORK IN THE POST OFFICE.

The eye work done by post-office employees consists principally of the reading of writing or typewriting, of different degrees of legibility, on envelopes or wrappers of various colors and surfaces. It is more difficult and more tiring to the eyes to read small fine characters than to read large well-marked ones, and it is also difficult and tiring to read writing in ink of certain colors against backgrounds of the same or certain other colors. It has been found, for instance, that black on yellow is more easily read than red on green.[1]

The amount of eye work varies in the different processes of the post-office work according to the amount of reading or writing required. A letter separator reads on an average between thirty and forty addresses a minute. His work may require adjustment of both the external and the internal muscles of his eyes 80 times a minute. If the intensity of light on the letter is different from that on the case, he has to adjust his eyes not only for distance but also for difference in illumination. There are also registered on his retina, at the rate of 40 a minute, the images of the addresses and, possibly, the images of the pigeonholes into which he puts the letters. Each image of an address must be clearly formed in order for him to read it correctly, and must be rapidly eradicated in order to give place to the succeeding image. It should be noted, however, that once the separator is familiar with the scheme of his boxes, he does not need to look at each pigeonhole every time he puts a letter into it.

If the illumination is low, blurred images are apt to result in the ametropic eye, because the dilated pupil brings out the refractive errors. The speed of vision is reduced, since it takes a longer time to see clearly. The excessive effort of the muscles of the eye to adjust for seeing results in ocular fatigue and in diminution of power to maintain clear vision. The frequent contractions of the ocular muscles in adjusting for poor illumination and for glare tend also to deform the eye and to cause additional refractive errors. Then, again, when the illumination is low and the object to be seen is brought closer for clear vision, there is a struggle between the muscles of the iris, one set tending to contract the pupil for accom-

[1] See Luckiesh, Color and Its Applications, 1921, page 137.

modation, as the object is brought nearer, and the other tending to dilate it, to admit more light. This also results in eye fatigue.

Because of the variation in the size of the pieces handled and the uncertainty of both the location and the character of the addresses, the newspaper separator averages about half as many pieces a minute as the letter separator. The same hindrances occur to a still greater extent in the work of the parcel post separator who handles approximately only half as many pieces a minute as the newspaper separator.

The work of those engaged in checking and auditing in the money-order division of the general post office and the work of those searching directories for addresses should also be considered as intensive eye work. The general clerical work done in the post offices does not differ from clerical work done in other places and is not more tiring to the eye.

The eye examinations of the postal employees were usually made at the post office in which they were employed. Certain examinations requiring the use of special instruments were made at the New York office of the Office of Industrial Hygiene and Sanitation of the United States Public Health Service.

METHOD OF EXAMINATION.

A record of each examination was made on a form drawn up especially for such a record. A reproduction of this form is shown in Figure 6. Although only the name and age of the employee are called for on the form, the sex and color were also recorded.

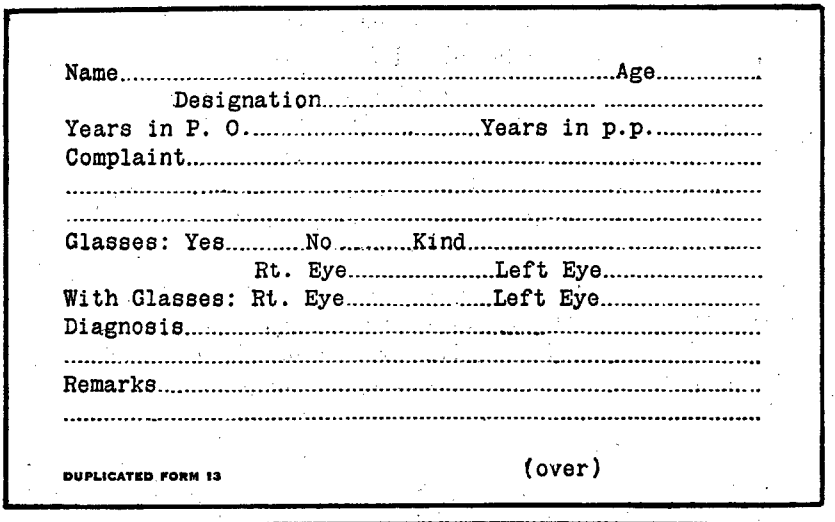
The occupational group to which the employee belonged according to the classification given in Tables III and IV was recorded under "Designation;" and under their respective headings were recorded the total length of service in the Post Office Department and the length of time in the present occupational group ("p. p.").[2]

To determine the ailments from which the employee suffered, the following questions were asked, "Have you any complaints to make concerning your eyes? Do you have headaches which you attribute to your eyes? Do your eyes tire while you are working? Does the light hurt your eyes? Does reading matter blur before your eyes?" According to the nature of the answers received to these questions, others were asked, and the answers were recorded.

Each employee was asked whether or not he wore glasses. If he wore glasses, information was obtained as to the total length of time he had worn them and as to how long he had been wearing the pair now in use. The glasses were then examined to determine whether they were spherical, cylindrical, compound, concave, convex,

[1] Present position.

or mixed. Information was also obtained from the employee as to whether or not frequent changes of glasses had been necessary, and from the glasses themselves, as to the kind and degree of the refractive error which they were intended to correct.



Name.....Age.....
Designation.....
Years in P. O.....Years in p.p.....
Complaint.....
.....
.....
Glasses: Yes.....No.....Kind.....
Rt. Eye.....Left Eye.....
With Glasses: Rt. Eye.....Left Eye.....
Diagnosis.....
.....
Remarks.....
.....

DUPLICATED FORM 13 (over)

Illumination Ft. Candles .....

FIG. 6.—Reproduction of front and back of card on which was kept the record of the eye examinations

The vision of each employee was tested at a distance of 20 feet. Snellen's chart was used, with an unlearnable chart as a check. Daylight illumination was used on the chart during the day, and after dark the chart was illuminated by a local light which gave an intensity of illumination of 15 foot-candles on the vertical plane

of the chart. Each eye was tested by itself with the other eye covered. The vision with and without glasses was recorded. If the subject missed only one letter on a line, he was asked to read the line carefully again, and if he corrected the mistake on the second reading and could read two letters on the next smaller line, he was then given credit for reading the line in which he missed one letter on the first reading. If he missed from two to four letters on any line, he was recorded as only partly reading that line. For example, if he read all the letters on the 20-foot line except the letter "Z" which he called "E," and the letter "P" which he called "F," he was marked as having a vision of 20/20, partly, in that eye. If he read all the letters on the 20-foot line except the letter "P" which he called "F," he would then be asked to read the line again carefully, and if he then read all the letters correctly and could read two letters on the line below, the 15-foot line, he was given a rating of 20/20 vision in that eye. If, however, on the second reading, he again miscalled a letter on the 20-foot line or reading all the letters on that line correctly could not read two letters on the 15-foot line, he was marked as having vision of 20/20, partly, in that eye. If, on the first reading, he read the 20-foot line correctly and could read more than half the number of letters on the 15-foot line, he was rated as having vision of 20/15, partly, in that eye. If he read the 20-foot line correctly but could read less than half the letters on the 15-foot line, he was marked as having 20/20 vision in that eye.

A diagnosis was made in every case if possible. Whenever the kind of refractive error could be determined quickly either by the corrective effect of the glasses used, or by actual refraction performed by the examining physician, it was recorded. When it could not be quickly determined, a simple diagnosis of ametropia was recorded. When there was 20/20 vision, or better, in each eye and there were no abnormalities found and no complaints were made by the patient, the diagnosis of normal was made. When there was 20/20 vision, or better, in each eye and no muscular unbalance could be shown although the patient complained of two or more symptoms of eye strain, the diagnosis of asthenopia was made. When the vision was 20/20, or better, in each eye and glasses which gave an improvement in vision were worn, the eye defect corresponding to the kind of glasses worn was noted. When distance vision of a person over 45 years of age was 20/20, or better, in each eye and glasses were worn for reading, presbyopia was added after the diagnosis of normal.

Under the heading for remarks were recorded whatever findings were observed after an examination of the eyelids, the conjunctiva,

the cornea, the iris, and the pupil. The shape of the pupil and its reaction to light were noted. The movements of the eyeball were taken in the usual manner.

On the back of the card were recorded the mean illumination of the specific area in which the individual was working and a rough estimate of the amount of glare in this area. From the post office record of each individual, information was obtained as to his location and the character of his occupation in the City Hall or general post office during the previous five years. Since the present lighting installation and gas-filled lamps have been in use for the same period of time, it was possible to estimate the approximate amount of illumination which the individual had worked under during the preceding five years.

The employees examined were told of any defects found, and were advised to consult their physicians as to what might be done to correct these defects.

EYE EXAMINATIONS IN THE CITY HALL AND GENERAL POST OFFICES.

In studying the effect of occupation or intensity of illumination on the vision of the post office employees, it would naturally have been of great advantage to have a record of the state of their vision at the time of their entrance examination for post office work. Since there was no such record available, the Civil Service Commission kindly furnished the visual findings of 300 post office employees, taken at random from their preliminary physical examinations for entrance into post office work. The requirement of the Civil Service Commission for post office employees is that vision shall not be less than 15/20ths in the poorer eye. The fact that the post office examiners, in determining vision, used 20 as a numerator instead of a denominator makes it somewhat difficult to compare the results of the examinations in this study with the post office requirements. However, roughly speaking, it is felt that the 15/20ths vision required by the post office is equivalent to approximately 20/25ths in the terminology here used. For this reason a vision of 20/20ths, partial or better, in one or both eyes was taken as normal in this investigation. Of the 300 post office employees whose visual records were furnished by the Civil Service Commission, 92.7 per cent had a vision of 20/20ths, or better, uncorrected, in one or both eyes; and this percentage, therefore, is taken to represent approximately the average vision of post office employees when entering the Government service.

Table XVI gives the distribution, by sex and color, of the 2,449 employees who were examined in the City Hall and general post

offices. In the City Hall post office 709 were examined, out of a total of 1,159 employees. In the general post office 1,740 were examined, out of a total of 2,536 employees. In both these post offices the white males constitute by far the largest class of employees, representing approximately 81 per cent. This point should be noted, because in the discussion that follows, the white male group alone has been considered, the other groups having been discarded because their numbers were too small for statistical analysis.

TABLE XVI.—*Distribution of the 2,449 employees examined in the New York City Hall and general post offices, by sex and color.*

Post office.	Number of employees examined.	White.			Colored.		
		Total.	Males.	Females.	Total.	Males.	Females.
City Hall	709	632	600	32	77	61	16
General	1,740	1,517	1,335	182	223	194	29
Total	2,449	2,149	1,935	214	300	255	45

Table XVII gives the distribution by occupation of the employees examined in both post offices.

TABLE XVII.—*Distribution of the 2,449 employees examined in the New York City Hall and general post offices, by occupation.*

Post office.	Total number.	Occupational distribution.						
		1	2	3	4	5	6	7
		Laborers.	Facers.	Parcel post separators.	Newspaper separators.	Executives, foremen, etc.	Clerks.	Letter separators.
City Hall	709	51	5	15	118	12	237	271
General	1,740	200	30	52	154	67	665	572
Total	2,449	251	35	67	272	79	902	843

Table XVIII gives a general comparison of all the employees examined in both post offices, irrespective of sex, color, or occupation, according to acuity of vision, refractive errors, and all abnormal and diseased conditions of the eye. The percentage of those having normal vision in one or both eyes is 57.5 per cent in the City Hall post office as compared with 67.4 per cent in the general post office. The percentage of refractive errors in the City Hall post office is 76.6 per cent, as compared with 72.5 per cent in the general post office. The percentage of inflammatory conditions in the City Hall post office is 20.9 per cent, as compared with 11.9 per cent in the

general post office. The percentage of muscular unbalance in the City Hall is 33.4 per cent, as compared with 22.4 per cent in the general post office. The percentage of asthenopia is 16.5 per cent in the City Hall, as compared with 5.7 per cent in the general post office. While this table is not adjusted for color, sex, age, or occupation, there seems to be a consistent difference in acuity of vision and in the number of refractive errors and diseased conditions of the eye between the City Hall post office and the general post office.

TABLE XVIII.—*Percentage of the 2,449 employees examined in the New York City Hall and general post offices, with certain eye conditions.*

Post office.	Normal vision in both eyes with no defects.	Normal vision in both eyes with defects.	Normal vision in one eye only.	Normal vision in one or both eyes.	Defective vision in both eyes.	Refractive errors.	Inflammatory conditions.	Muscular unbalance.	Asthenopia.
City Hall	10.3	29.5	17.8	57.5	42.5	76.6	20.9	33.4	16.5
General	19.8	29.9	17.6	67.4	32.6	72.5	11.9	22.4	5 7

In Table XIX all the eye diseases and defects are listed in detail, and the frequency and the percentage distribution in each post office are given. As this table is practically Table XVIII in detail, with the addition of the eye diseases found, the remarks which applied to Table XVIII apply also to Table XIX.

TABLE XIX.—*Percentage of employees with eye diseases and defects, by post offices.*

	City Hall post office.		General post office.		Both post offices.	
	Number of cases.	Per cent distribution.	Number of cases.	Per cent distribution.	Number of cases.	Per cent distribution.
Number of employees examined	709	.....	1,740	.....	2,449	.....
Normal, no defects	73	10.3	345	19.8	418	17.1
One refractive error, or more	543	76.6	1,261	72.5	1,804	73.7
Myopia	66	9.3	155	8.9	221	9.0
Hyperopia	94	13.3	192	11.0	286	11.7
Ametropia	310	43.7	745	42.8	1,055	43.1
Presbyopia	98	13.8	213	12.2	311	12.7
Astigmatism	67	9.4	208	11.9	275	11.2
Amblyopia	18	2.5	36	2.1	54	2.2
Anisometropia	4	.6	13	.7	17	.7
Using glasses	278	39.2	589	33.8	867	35.6
One inflammatory condition, or more	148	20.9	207	11.9	355	14.5
Conjunctivitis	133	18.8	177	10.2	310	12.6
Follicular conjunctivitis	4	.6	6	.3	10	.4
Blepharitis	13	1.8	38	2.2	51	2.1
Trachoma	4	.6	4	.2	8	.3
Iritis	.....	.0	1	.06	1	.04
Retinitis	1	.1	.....	.0	1	.04
One muscular unbalance, or more	237	33.4	389	22.4	626	25.6
Exophoria	204	28.8	325	18.7	529	21.6
Esophoria	32	4.5	56	3.2	88	3.6
Escotropia	2	.3	10	.6	12	.5
Asthenopia	117	16.5	99	5.7	216	8.8

TABLE XIX.—*Percentage of employees with eye diseases and defects, by post offices*—Continued.

	City Hall post office.		General post office.		Both post offices.	
	Number of cases.	Per cent distribution.	Number of cases.	Per cent distribution.	Number of cases.	Per cent distribution.
Other diseases:						
Arcus senilis	35	4.9	25	1.4	60	2.5
Corneal opacity	11	1.6	13	.7	24	1.0
Photophobia	14	1.9	5	.3	19	.8
Lacrimation	5	.8	7	.4	12	.5
Contusion	2	.3	8	.5	10	.4
Cataract	3	.4	6	.3	9	.4
Nystagmus	7	.9	1	.1	8	.3
Coloboma	4	.6	1	.1	5	.2
Pterygium	2	.3	3	.2	5	.2
Cyst	1	.1	3	.2	4	.16
Squint	3	.4	1	.1	4	.16
Ptosis	3	.4	.....	.0	3	.12
Epiphora	2	.3	1	.1	3	.12
Strabismus	1	.1	2	.1	3	.12
Blindness	.....	.0	3	.2	3	.12
Synechia	.....	.0	3	.2	3	.12
Leukoma	2	.3	.....	.0	2	.08
Glaucoma	2	.3	.....	.0	2	.08
Cicatrix	1	.1	1	.1	2	.08
Trauma	1	.1	1	.1	2	.08
Presence of foreign body	1	.1	1	.1	2	.08
Loss of eye	1	.1	1	.1	2	.08
Tumor on lid	.....	.0	2	.1	2	.08
Misshapen pupil	.....	.0	2	.1	2	.08
Follicles on lid	1	.1	1	.1	2	.08
Vertical oscillation	1	.1	0	.0	1	.04
Distortion of pupil	1	.1	.....	.0	1	.04
Hordeolum	1	.1	.....	.0	1	.04
Optic atrophy	1	.1	.....	.0	1	.04
Retinal stretch	1	.1	.....	.0	1	.04

TABLE XX.—*Percentage of employees having certain eye conditions, by sex, color, and post office, together with the average age and average years of service.*

Color, sex, and post office.	Number of employees examined.	Average age.	Average years of service.	Percentage with certain eye conditions.							
				Normal in both eyes.	Normal in one eye.	Normal in one eye or both eyes.	Defective eyes.	Refractive errors.	Inflammatory conditions.	Muscular unbalance.	Asthenopia.
WHITE.											
Males:											
City Hall	600	36.9	11.9	38.3	17.9	56.2	43.8	76.4	22.1	32.2	16.2
General	1,335	36.4	10.5	47.6	16.6	65.2	34.8	73.9	13.8	22.6	5.0
Both unadjusted	1,935	36.5	10.9	44.8	17.0	62.4	37.6	74.7	16.4	25.6	8.5
Both adjusted [1]				47.1	17.2	64.3	35.7	74.2	16.6	25.7	8.6
Females:											
City Hall	32	26.0	3.6	37.5	18.8	56.3	43.7	84.3	21.9	46.9	21.9
General	182	30.2	3.6	47.2	24.7	71.9	28.1	70.0	7.5	21.4	5.9
Both unadjusted	214	29.7	3.6	46.2	23.8	70.0	30.0	72.5	9.6	25.2	8.3
Both adjusted [1]				40.7	22.2	62.9	37.1	77.2	10.0	25.4	7.5
COLORED.											
Males:											
City Hall	61	35.7	7.1	49.2	19.7	68.9	31.1	70.1	12.2	31.6	14.9
General	194	36.1	6.8	59.8	17.0	76.8	23.2	65.2	3.6	21.8	7.6
Both unadjusted	255	36.0	6.9	57.3	17.6	74.9	25.1	66.4	5.6	24.0	8.8
Both adjusted [1]				57.5	17.9	75.4	24.6	66.7	6.0	23.9	8.6
Females:											
City Hall	16	27.6	2.5	56.3	6.3	62.6	37.3	93.5	.....	60.0	26.6
General	29	29.1	2.5	62.1	10.4	72.5	27.5	68.9	6.8	20.6	27.9
Both unadjusted	45	28.6	2.5	60.0	8.9	68.9	31.1	77.2	4.5	34.1	27.7
Both adjusted [1]				51.6	8.2	59.8	40.2	83.6	4.7	33.7	20.7

[1] Adjusted to standard age distribution of workers.

In Table XX, acuity of vision, refractive errors, muscular conditions and diseases of the eye in the City Hall post office are compared with those in the general post office. From the table it will be seen that the different groups in the two post offices have about the same average age and the same average number of years of service. This table, therefore, shows that there is approximately the same difference in percentage of normal vision between the employees in the general post office and those in the City Hall post office that was found in Table XVIII. In each of the four sex-color groups, the percentages of normal vision in the general post office are greater than those in the City Hall post office. The reverse is true of the percentages of refractive errors, inflammatory conditions, muscular unbalance, and asthenopia, except for the group of colored females, where the percentage of asthenopia is slightly higher for the general post office than for the City Hall post office.

COMPARISON OF NORMAL VISION IN ONE EYE OR BOTH EYES BY AGE, SEX, AND COLOR.

In undertaking to compare the percentage distribution of normal vision in the groups by sex and color, the most important factor to be studied, in order that the visual acuity of these groups may be accurately compared, is the variation of normal vision with age. In Table XXI the percentages of normal vision, according to sex and color, are shown for eleven 5-year age groups, covering all ages from 18 to 70 years of age. They are also given for all employees under 45 years of age, for all employees over 45 years of age and for all employees taken altogether. From the averages for the last, which have been weighted according to age, it will be seen that the colored males have the greatest percentage of normal vision, with 74.9 per cent normal; the white females are second, with 70.1 per cent normal; the colored females are third, with 68.8 per cent normal; the white males last, with 62.4 per cent normal. In the under-45-years age group, the colored males again have the highest percentage of normal vision, with 80.9 per cent normal, while the other three groups have approximately the same percentage of normal vision, the white males having 70.2 per cent, the white females 71.1 per cent, and the colored females 68.8 per cent. In the over-45-years age group, the white male group has much the lowest percentage, having only 35 per cent normal vision. The most important point brought out by this table is the slight change in the percentage of normal vision in the various age groups under the age of 45 years. Among the white males the percentage of normal vision is 73.5 in the age group of 20 to 25 years as compared with 70.6 normal vision in the age group of 40 to 45 years. The values of the percentages in the age groups under 45

and their rather irregular distribution seem to indicate that in the white males, at least, very little change in acuity of vision takes place from 20 to 45 years of age. After the age of 45 years the decrease of normal vision is very marked. In the colored males the 45 to 50 years age group shows the same definite decrease in the percentage of normal vision as does the same age group for the white males. For both the white and the colored females, in a rather general way, the same irregular distribution seems to prevail, although in the 40 to 45 and in the 45 to 50 years age groups the numbers are so small as to make the results unreliable.

TABLE XXI.—*Number and percentage of employees having normal vision, by age, sex, and color, in both post offices.*

NUMBER.

Age groups.	Normal in both eyes (white males).	Normal in one eye or both eyes.				Total.
		White.		Colored.		
		Male.	Female.	Male.	Female.	
18–20	18	21	1	.....	.....	22
20–25	164	214	72	30	13	329
25–30	201	248	38	41	7	334
30–35	170	236	18	36	5	295
35–40	122	176	11	35	5	227
40–45	101	163	5	28	1	197
45–50	60	88	5	12	.....	105
50–55	19	35	.....	6	.....	41
55–60	10	14	.....	2	.....	16
60–65	1	11	.....	1	.....	12
65–70	.....	2	.....	.....	.....	2
Under 45	776	1,058	145	170	31	1,404
Over 45	90	150	5	21	0	176
Total	866	1,208	150	191	31	1,580

PERCENTAGE.

20–25	56.4	73.5	75.8	85.7	76.5	75.1
25–30	59.3	73.2	77.6	82.0	50.0	73.9
30–35	49.3	68.4	66.7	75.0	83.3	69.2
35–40	45.4	65.4	61.1	94.5	83.3	68.8
40–45	43.7	70.6	38.4	70.0	.....	68.9
45–50	35.3	51.8	71.4	54.5	.....	52.8
50–55	16.4	30.1	.....	35.3	.....	30.6
55–60	13.0	18.2	.....	.....	.....	19.3
60–65	.....	19.6	.....	.....	.....	21.1
65–70	.....	.....	.....	.....	.....	.....
Under 45	51.5	70.2	71.1	80.9	68.8	71.4
Over 45	21.0	35.0	50.0	46.6	.....	36.4
Total	44.8	62.4	70.1	74.9	68.8	64.5

For the reasons given above, in some of the tables that follow, the white males have been divided into two groups, those over and those under 45 years of age, and in the under-45-years age group age itself is not considered as an important factor. The accompanying graph (fig. 7) shows the manner in which the percentage of normal vision varies with age.

NORMAL VISION AND CERTAIN EYE DISEASES FOR WHITE MALES, BY OCCUPATIONS.

It will be seen from Table XX that the number of white females, colored males, and especially, colored females examined is so small for each group that an attempt to distribute them into various occupational groups would be impracticable. The idea of such grouping has therefore been discarded, and a detailed analysis has

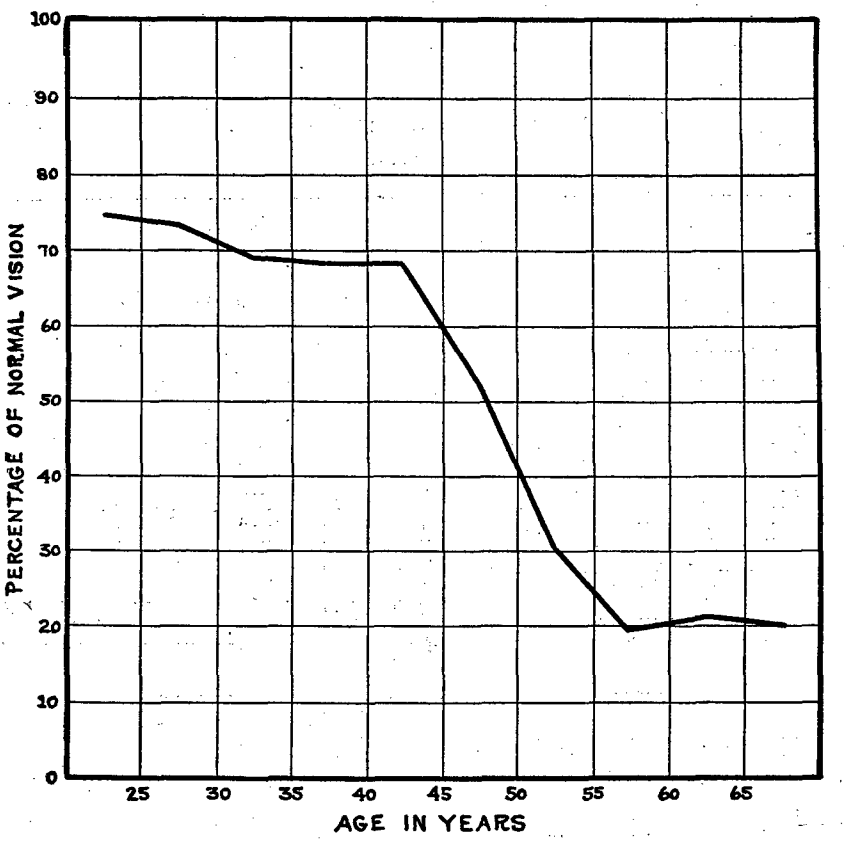


FIG. 7.—Percentage of normal vision in one eye or both eyes for 2,449 employees of the New York City Hall and general post offices, by 5-year age groups

been made of the occupational groups among the white males only. In the section of this report that refers to the process studies, the employees of the post office were divided into seven occupational groups: Laborers, facers, parcel-post separators, executives, newspaper separators, clerks, and letter separators. In this classification it was intended to group occupations according to intensity of eye work performed. Since, as will be seen in Tables III and IV, the numbers examined in the occupational groups of the facers, parcel-post separators, and executives were very small, and since, furthermore,

the eye work performed by these groups is of about the same amount and intensity, they may be combined into one group.

TABLE XXII.—*Percentage of white males under and over 45 years of age, according to eye conditions, in both post offices, by occupations.*[1]

	Under 45 years of age.					Over 45 years of age.				
	Laborers.	Others.[2]	Newspaper separators.	Clerks.	Letter separators.	Laborers.	Others.[2]	Newspaper separators.	Clerks.	Letter separators.
Number of employees examined	134	105	186	533	528	52	66	30	205	81
Percentage with certain eye conditions:										
Normal in one eye or both eyes	81.4	70.5	67.7	73.0	65.5	38.5	31.8	30.0	37.1	29.6
Refractive errors	56.0	68.6	72.0	70.2	74.6	88.5	86.6	93.3	91.4	90.1
Inflammatory conditions	12.7	13.4	17.7	17.6	20.9	13.5	9.0	20.0	21.2	27.2
Muscular unbalance	16.4	19.0	30.4	23.9	30.7	13.5	22.4	13.3	24.7	18.5
Asthenopia	1.5	2.9	12.2	8.2	7.9	1.9	0.0	3.3	3.5	18.5

[1] Fifteen of the white males examined were not classified as to occupation, because they were substitutes.
[2] Others include facers, parcel-post separators, and executives.

In Table XXII, therefore, in which the percentages of normal vision in one eye or both eyes and the disease rates are given for white males, in different occupational groups, a classification in five occupational groups rather than seven has been used. It will also be seen that in this table the white males have been divided into two groups: Those under 45 years of age and those over 45 years of age, respectively. From this table it appears that except for the position of the clerks, there is, in regular sequence, in both age groups, a reduction in percentage of normal vision, the percentages ranging in the under-45-years age group, from 81.4 per cent of normal vision for the laborers, to 65.5 per cent for the letter separators, and in the over-45-years age group, from 38.5 per cent for the laborers to 29.6 per cent for the letter separators. As remarked above, our classification of the occupational groups was based upon an estimate of the amount and intensity of the eye work performed by each group; and it is possible that the amount and intensity of eye work performed by the clerks was overrated, since it appears that their percentage of normal vision in both the under-45 and over-45 years age groups is lower than that of the laborers. Since it was planned in the original classification to arrange the occupational groups according to the amount and intensity of eye work performed, beginning with the group which was regarded as having the least eye strain and ending with that having the greatest, and since the percentage of normal

vision in any group may be taken to indicate the amount and intensity of eye work performed by the group, it would seem that this classification, except for the position of the clerks, is correct. Although there may be some question as to the amount and intensity of the eye work performed by the groups intervening between the laborers and the letter separators, there can be none as to the wide difference in the amount and intensity of the eye work performed by these two groups; and this difference is reflected in the differences between the percentages of normal vision and the percentages of defects and diseases of the eye for these two groups, shown in Table XXII in every case.

In the discussion of Table XXI attention was directed to the fact that for white males there was very little change in visual acuity with age until the age of 45 years had been reached. In Table XXIII the percentage distribution of eye conditions among white males under 45 years of age has been tabulated according to length of service, to determine as far as possible the effect of length of service in a group where apparently the age condition is an unimportant factor. Where the length of service is less than a year, the percentage of normal vision in one eye or in both eyes is, as shown by this table, 79.5 per cent in the City Hall post office as compared with 78.5 per cent in the general post office. Where the service is from one to five years, the percentage of normal vision in the City Hall post office is 64.6, as compared with 73.5 in the general post office. With from 5 to 10 years' service, the percentage of normal vision in the City Hall post office is 62.4 per cent, as compared with 75 per cent in the general post office. Where the length of service is over 10 years, the percentage of normal vision is 63.9 in the City Hall post office, and 63.9 also in the general post office. It seems apparent from this table that the vision of those who have served less than one year in either or both of the post offices is better than the vision of those who have served for a longer time. It will be remembered that the data obtained from the Civil Service Commission showed that approximately 92.7 per cent of the employees had normal vision when they entered the Government work. It appears, therefore, that there has been a reduction of approximately 14 per cent during the first year of service in each post office. Comparison of the one to five years of service group with the under one year of service group shows that there has again been a decrease of approximately 14 per cent in vision in the City Hall post office, and of approximately 5 per cent in the general post office. Comparing the 5 to 10 years of service group with the 1 to 5 years of service group, we find the decrease to be approximately 2.2 per cent in the City Hall post office, with apparently a slight increase of 1.5 per cent in the general post office. Employees who have given 10 years of

service in both the post offices have exactly the same percentage of normal vision; namely, 63.9.

TABLE XXIII.—*Percentage of white males under 45 years of age, according to eye conditions, by length of service, in the two post offices.*

CITY HALL POST OFFICE.

Length of service (in years).	Number of employees examined.	Percentage distribution according to eye conditions.							
		Normal in both eyes.	Normal in one eye.	Normal in one eye or both eyes.	With defective eyes.	With refractive errors.	With inflammatory conditions.	With muscular unbalance.	With asthenopia.
Under 1	39	64.1	15.4	79.5	20.5	52.4	21.4	30.9	9.5
1–5	178	44.9	19.7	64.6	35.4	76.6	27.2	32.6	17.9
5–10	77	41.6	20.8	62.4	37.6	65.1	48.9	34.8	18.5
Over 10	166	44.0	19.9	63.9	36.1	75.9	22.9	37.4	17.5
GENERAL POST OFFICE.									
Under 1	149	65.1	13.4	78.5	21.5	65.9	12.0	14.5	2.7
1–5	411	56.0	17.5	73.5	26.5	69.6	11.1	23.0	7.7
5–10	188	55.3	19.7	75.0	25.0	68.9	12.3	26.7	5.0
Over 10	288	46.9	17.0	63.9	36.1	72.5	11.1	27.9	5.7

Two points are of interest in this comparison; first, that in the groups embracing from 1 year to 10 years' length of service, the vision in the general post office is much better than in the City Hall post office, while the vision in both the post offices in the over-10-years-of-service group is the same; second, the percentage of normal vision in each of the length-of-service groups of over one year in the City Hall post office tends to remain practically the same; that is, 64.6 per cent from 1 to 5 years, 62.4 per cent from 5 to 10 years, and 63.9 per cent over 10 years; while in the general post office the vision for the length-of-service groups 1 to 5 and 5 to 10 remains nearly constant, but in the over-10-years-of-service group it drops to that of the City Hall post office. There does not seem to be any marked difference in the percentage of refractive errors between the City Hall and general post offices, the percentage being about the same for both post offices with a tendency to increase with length of service. The percentage distribution of inflammatory conditions, muscular unbalance, and asthenopia is, however, much higher in the City Hall post office than in the general post office for each length-of-service group. There is, however, no marked tendency for these latter conditions to increase according to length of service.

In Table XXII the percentage of normal vision in the occupational group, where there is the most intensive eye work, is shown to be less than in the other occupational groups, especially in the case of the first group; and Table XXIII shows that there is a considerable reduction in the normal vision of an employee during the

first year, and that there are also reductions during the succeeding years. Therefore, an attempt was made to determine whether or not there is a greater degree of reduction in normal vision with length of service for letter separators—the occupational group requiring the most intensive eye work—than for all employees taken together. In Table XXIV is given the percentage distribution of white males under 45 years of age having normal vision in one eye or both eyes, and in both eyes, first, for all employees in all occupations, and second, for letter separators only.

TABLE XXIV.—*Percentage of white males under 45 years of age having normal vision in one eye or both eyes, and in both eyes, for all employees, and for letter separators only, by length of service in each post office.*

Length of service (in years).	Normal vision in one eye or both eyes.				Normal vision in both eyes.			
	All employees.		Letter separators only.		All employees.		Letter separators only.	
	General post office.	City Hall post office.	General post office.	City Hall post office.	General post office.	City Hall post office.	General post office.	City Hall post office.
Under 1	78.5	79.5	62.9	81.8	65.1	64.1	54.3	54.5
1–5	73.5	64.6	72.3	70.0	56.0	44.9	53.7	50.0
5–10	75.0	62.4	70.1	53.6	55.3	41.6	55.2	25.0
Over 10	63.9	63.9	60.0	45.8	46.9	44.0	48.8	23.7

Several important points are brought out by this table. It is seen that acuity of vision for the letter-separators is, in general, lower than that for all the employees taken together in the corresponding post office. In the general post office, in the one-to-five-years-service group the letter separators have a somewhat lower percentage of normal vision. In the five-to-ten-years-service group the percentage is even lower. In the over-10-years-service group the letter separators again have a lower percentage, the reduction in vision with length of service being proportionately the same as that for all the employees together. In the City Hall post office, in the one-to-five-years-service group the percentage of normal vision among the letter separators is greater than among all the employees together. In the five-to-ten-years-service group the percentage of normal vision for the letter separators is approximately 9 per cent below that for all the employees together, while in the over-10-years-service group this difference has increased to approximately 18 per cent. It should further be noted from this table that here again in all the length-of-service groups the percentage of normal vision among the letter separators in the City Hall post office is generally below that of the letter separators in the general post office. It is believed that this table tends to bear out the general conclusion arrived at from Tables XXII and XXIII, that the percentage of normal vision is lower in

the occupational group in which the most intensive eye work is done and that the percentage of normal vision in the group where the most intensive eye work is done bears a much more definite relation to the length of service than it does in the other groups.

RELATION OF ILLUMINATION TO ACUITY OF VISION.

As has been stated several times before, in every table a constant difference has been found between the percentage of normal vision in the City Hall post office and that in the general post office. In practically every table, as the factors of sex, color, age, length of service, and occupation have been eliminated, the difference has still remained. As far as we are able to determine by the study of the conditions in these two post offices, there remains but one other factor, not yet discussed, which may be considered as the cause of the difference in visual acuity between these two post offices, and that is illumination.

If reference is made to Tables V, VIII, IX, XII, and XIII, the difficulty of comparing accurately the artificial illumination in these two post offices will be immediately realized. The mean illumination of each work floor is known for each post office, as is the mean illumination of all work floors for each post office, but it is felt that the difference—namely, 0.2 foot-candles—between the mean artificial illumination in the City Hall post office, which is 3.4 foot-candles, and the mean artificial illumination in the general post office, which is 3.6 foot-candles, is not a fair measure of the total difference in the illumination, since it does not take into account the arrangement of the lighting, the excessive amount of glare in the City Hall post office, the abrupt changes from one degree of illumination to another—much more frequently found in the City Hall post office than in the general post office—the number of employees working under different degrees of illumination, and, most important of all, the facts that only 5 per cent of the employees at the City Hall post office work under part-time daylight, in contrast with 40 per cent of the employees at the general post office, and that only 3 per cent of the employees in the City Hall post office work under all daylight, in contrast with 21 per cent of the employees of the general post office. In this study an attempt was made originally to determine for every employee examined the average successive illuminations that he had worked under during the past five years, based, of course, upon the mean illumination found in the various working areas at the time of this study, since the present arrangement and intensity of lighting in the two post offices have remained fairly constant over this period of time. It is realized, however, that even with the present lighting system unchanged, many variations

are possible in the amount of light produced by the same installation, on account of the accumulation of dirt on the fixtures and the aging of lamps, and also, perhaps, the use of lamps of different wattages. Though an attempt was made, by studying groups of employees working under various degrees of artificial illumination, to ascertain whether there was any direct relationship between illumination and acuity of vision on account of the presence of many other factors which were not measured but which had to be considered in making such a comparison, it was not possible to find any consistent relationship between the intensity of artificial illumination and visual acuity. It is believed, however, that the inability to find a relationship was due rather to the fact that the data were incomplete than that such a relationship does not exist. It is possible that if comparison could be made of groups of employees doing the *same kind of work* under different illuminations, a difference in the percentage of normal vision in these groups would be found. Another element which must be taken into consideration is the fact that the few comparisons that were possible in this survey had to be made within a small range of artificial illumination. Unfortunately, in the study of the New York post offices, groups of employees were not found working under high intensities of artificial illumination, and therefore a comparison of corresponding groups working under high and low degrees of illumination could not be made.

COMPARISON OF THE NORMAL VISION OF WORKERS IN THE POST OFFICE WITH THE NORMAL VISION OF WORKERS IN OTHER OCCUPATIONS.

In Table XXV is shown the percentage of normal vision, in one eye or both eyes, for white males in 10 industries arranged in 10-year age groups. The number examined in each age group is also given.[3] The industries are arranged in ascending order of mean

TABLE XXV.—*Total number of workers and percentage with normal vision in one eye or both eyes in 10 industrial groups of white males, by 10-year age groups.*

TOTAL NUMBER OF WORKERS.

Occupational group.	Age group.						
	Under 20.	20–30	30–40	40–50	50–60	Over 60.	Total.
Garment industry	38	837	682	266	81	11	1,915
Chemical industry	32	329	300	129	34	6	830
New York post offices	32	630	614	401	193	65	1,935
Glass industry	131	459	390	277	130	62	1,449
Steel industry	55	384	303	124	38	1	905
Gas industry	7	99	101	56	21	.....	284
Pottery industry	25	40	59	60	39	6	229
Foundry industry	30	253	431	297	131	27	1,169
Cigar industry	49	119	102	73	27	14	384
Cement industry	17	76	59	47	14	2	215

[3] The percentages are not given where there are less than 10 individuals in a group.

TABLE XXV.—*Total number of workers and percentage with normal vision in one eye or both eyes in 10 industrial groups of white males, etc.*—Contd.

PERCENTAGE WITH NORMAL VISION.

Occupational group.	Age group.						
	Under 20	20–30	30–40	40–50	50–60	Over 60.	Total.
Garment industry	47.4	49.4	45.3	30.8	11.1	18.2	43.6
Chemical industry	84.4	58.7	53.0	32.6	5.9	.....	51.3
New York post offices	65.6	73.3	67.1	62.6	25.4	20.0	62.4
Glass industry	89.3	80.6	78.2	62.9	23.1	11.2	68.8
Steel industry	71.0	80.0	67.7	53.2	21.0	.....	69.2
Gas industry	.....	80.8	65.2	55.4	23.3	.....	70.1
Pottery industry	96.0	82.5	86.4	61.6	35.9	.....	70.7
Foundry industry	86.6	88.9	89.3	75.1	40.4	11.1	78.3
Cigar industry	95.9	89.9	85.3	65.8	44.5	7.1	78.6
Cement industry	100.0	94.7	94.9	82.9	42.9	.....	88.8

normal vision, no adjustment having been made for age distribution. The figures in this table were obtained from physical examinations conducted in these industries during the past few years by officers of the United States Public Health Service. The results of some of these examinations have already been published,[4] and others are under preparation for publication.

TABLE XXVa.—*Percentage of workers with normal vision in one eye or both eyes in 10 industrial groups of white males, adjusted to the age distribution of the total number of workers in the 10 groups.*

Industrial group	Percentage with normal vision in one eye or both eyes
Garment industry	40.9
Chemical industry	47.9
Gas industry	61.3
New York post offices	64.2
Steel industry	64.4
Glass industry	71.1
Pottery industry	75.2
Cigar industry	79.0
Foundry industry	81.0
Cement industry	86.9

In Table XXVa the mean normal vision for each industrial group has been adjusted to the age distribution of the total number of workers examined in the 10 industrial groups. It will be seen that this adjustment changes slightly the values of the mean normal vision. The garment industry, however, still has the lowest percentage of normal vision, the cement industry the highest, and the steel industry in both cases is the fifth on the list. The positions of the chemical and pottery industries also remain unchanged. It is seen that the industries may be arranged in ascending order according to the adjusted percentage of normal vision, beginning with that having the lowest percentage, as follows: garment, chemical, gas, post office, steel, glass, pottery, cigar, foundry, and cement.

[4] Studies in vocational diseases, Schereschewsky and Tuck, Public Health Bulletin No. 71; and Lead poisoning in the pottery trades, Newman, McConnell, Spencer, and Phillips, Public Health Bulletin No. 116.

PART II.

V. CHARACTER AND INTENSITY OF THE ILLUMINATION REQUIRED FOR POST OFFICE WORK.

NATURE OF THE EYE WORK IN POST OFFICES.

The data presented so far in this study are believed to be sufficient to warrant certain definite conclusions: First, that certain of the occupational processes require a high degree of intensive eye work; second, that in the two post offices studied there is at the present time no attempt to adjust the illumination to the intensity of the eye work performed by the different occupational groups nor to give equal, or even sufficient, illumination in any occupational group; and third, that both the intensity of the eye work and the amount of illumination under which the work is performed have a very definite relation to the condition of the eyes and to the number of eye defects found. If these conclusions are accepted, the question naturally arises as to what are the most desirable qualities and quantities of illumination for the different post office processes. The primary considerations are the nature of the work processes, the character of the working planes, and the color and surfaces of the materials handled.

The work processes have already been considered at length in the second section of this bulletin.

In most of the post-office work there are two working planes, the primary plane being approximately horizontal and the secondary vertical. Most of the eye work requires reading or writing on a single surface, in contrast to work involving the use of depth, such as machine work, millinery, or tailoring. This is true of both vertical and horizontal planes, and is a factor in the choice of lighting methods for such work. The height of the horizontal working plane, usually 45 inches above the floor, varies somewhat as the mail passes through the hands of the worker, while the distance of the vertical plane from the eye remains nearly the same, the vertical plane being usually the surface of a separation case.

Many different colors and combinations of colors are used in mail matter. Although black on a light or white surface predominates, there are numerous combinations which are decidedly difficult to

read, handicapping the worker and straining his eyes—such, for instance, as dark backgrounds with ink of the same color but of slightly lighter shade, and combinations of colors which do not present any great contrast, such as black on blue, brown on buff, purple on violet, and red on red. The envelopes coming from central Europe are nearly all colored. In order to read the addresses on the foreign mail and to distinguish the markings on foreign stamps a particularly good light is required. In the money-order and registry departments the post office uses blue and red cards, which must be handled in large numbers by the employees, and which are difficult to read and tiring to the eyes. Envelopes with a glossy surface and window envelopes, which not only have a glossy surface, but present the added difficulty of reading the addresses through the transparent paper, occur frequently in the mails. While the economic value of window envelopes must be acknowledged, they undoubtedly tax the eyes when they are handled in volume. Names and addresses on wrappers of newspapers and magazines, longhand addresses, and addresses on foreign mail are often difficult to read.

NATURE OF THE ILLUMINATION DESIRED.

It is desirable that the light used should be as diffuse as possible, since such light softens shadows and reduces glare. A completely diffusing system of lighting would disperse the light in all directions, and the illumination would be the same on all surfaces; but this would not be satisfactory, for it would destroy all shadows and consequently all appearance of shape. Uniformity of lighting is to be desired, however, on the working plane in the post office, and it is particularly desirable that there shall be no sharply contrasting areas of light and darkness on the working plane, because the rapid readjustment of the eye to successive light and dark areas is apt to produce fatigue and strain.

Some kinds of work require more light than others. For instance, the work of clerks requires more light than that of laborers. The American Standard Code of Lighting gives 5 to 10 foot-candles as necessary for the former, and 2 to 5 foot-candles for the latter. The eye work done in the post office may for the most part be classed with the eye work of other office workers, and in certain occupational groups, letter separators for instance, is as difficult as that for which the American Standard Code of Lighting recommends 10 to 20 foot-candles or more. Since the general level of artificial illumination is rapidly rising in this country, it is impossible to say what will ultimately be decided upon as the best illumination for post-office work, but it is probable that a much higher illumination will be required than that indicated at the present time.

GENERAL LEVEL OF ILLUMINATION.

The intensity of illumination that is required for any particular kind of work will be determined by the nature of the work. The intensity that will be desirable for a particular area, however, will depend more or less upon the general level of the surrounding illumination. If, for instance, the illumination in a certain area of one of the workrooms of the post office is raised above the general level, say from 3.5 to 10 foot-candles, then, to workers going from this brighter area to a darker one, the darker area will appear to be insufficiently illuminated, since the workers' eyes will have become adapted to the higher illumination. Therefore, in order to increase the illumination in any given area advantageously, the general level of illumination of all surrounding areas must be raised. Thus, when the illumination was raised in the third aisle of the separation cases on the mezzanine floor of the City Hall post office from 1.8 foot-candles to 3.9 foot-candles, the workers at the desks in the adjacent aisle immediately felt the need of greater illumination in that aisle, and several of the lamps were changed from 100 to 200 watts without any suggestion from the investigators or consultation with them.

It may be taken as a general principle that the illumination in any given area can not be appreciably increased above the general level without some increase in the general level.

That the general level of illumination is rapidly increasing is shown by figures given in textbooks and lighting codes published during the last 10 years. For instance, Bell,[1] in 1912, said, "Nearly all classes of clerical and office work can be performed easily under an illumination of 3 to 4 foot-candles"; and in "Light; Its Use and Misuse, A Primer of Illumination," prepared under the direction of the Illuminating Engineering Society, published in the same year, it is stated, on pages 19 and 20, that "ordinary reading, writing, or work on white or light-colored material can comfortably be carried on by most people with an illumination of 2 to 3 foot-candles." Clewell,[2] in 1913, gave 3 foot-candles as a good working intensity for office lighting. In 1917 Cravath, Harrison, and Pierce[3] gave 3 to 7 foot-candles as desirable illumination for office work, and Croft,[4] in the same year, recommended 4 foot-candles for office work. The "Code of Lighting for Factories, Mills, and Other Work Places" published by the United States Public Health Service in 1919, recommended 4 to 8 foot-candles for office work. In the "American Standard Code of Lighting," prepared under the direction of the Illuminating Engineering Society and issued by them in 1922, this recommendation

[1] The Art of Illumination, McGraw-Hill Book Co., p. 234.
[2] Factory Lighting, McGraw-Hill Book Co., p. 23.
[3] Illumination Engineering Practice, McGraw-Hill Book Co., p. 61.
[4] Practical Electric Illumination, McGraw-Hill Book Co., p. 133.

is advanced to 5 to 10 foot-candles. The State codes of lighting, beginning with the Pennsylvania Code in 1916, show that much higher standards have prevailed during the last few years, and also that there is a tendency toward a still higher level. For instance, Wisconsin, in 1917, recommended 3.5 to 6 foot-candles, and in 1921, 4 to 15 foot-candles, for office work. The "Code of Lighting for School Buildings," prepared by the Illuminating Engineering Society in 1918, recommended 3.5 to 6 foot-candles for class rooms and study rooms, with a minimum of 3 foot-candles, whereas the School Lighting Code of the State of Wisconsin for 1921 recommended 8 foot-candles and higher, with a minimum of 5 foot-candles, for the same class of work.

The recommendations of the State codes are given chronologically in Table XXVI.

TABLE XXVI.—*Illumination for office work as recommended in the State codes of lighting.*

Year.	State.	Intensities in foot-candles.		Year.	State.	Intensities in foot-candles.	
		Good practice.	Minimum.			Good practice.	Minimum.
1916.....	Pennsylvania.....	4.0- 8.0	3.0	1919.....	Oregon.....	4.0- 8.0	3.0
1917.....	Wisconsin.....	3.5- 6.0	2.75	1920.....	Ohio.....	4.0-12.0	3.0
1918.....	New Jersey.....	4.0- 8.0	3.0	1921.....	Wisconsin.....	4.0-15.0	3.0
1919.....	California.....	4.0-12.0	.....	1923.....	Massachusetts.....	6.0- 8.0	3.0

One reason for the increase in the intensity of illumination recommended for various eye occupations may be that the great progress made in the manufacture and design of lighting units, globes, and reflectors has made it possible to have higher intensities of illumination without increased brightness of the source, so that lamps of high wattage may now be inclosed in opal or other diffusing globes without causing objectionable glare from the high brightness of the surface of the units.

GLARE AND SURFACE BRIGHTNESS.

Almost as important as sufficient illumination is the reduction of glare. Intensity of illumination and reduction of glare may be considered as the two elements of the subject, and one is almost as fundamental as the other.

Glare is caused by intrusion of nonuseful light on the retina. No matter how well illuminated the objects on the working plane may be, clear vision of them may be destroyed by bright images of foreign objects in the field of vision. Glare may be produced by small bright sources of light in the field of vision; by a light lying within a small angle from the object looked at; by a large source

of light close to the eye; by a light standing out against a dark background; by exposure of the eye to a source of light during a long period of time; and by light reflected into the eye from polished surfaces or glossy paper. The elements of glare are then: (1) The brightness of the object producing it; (2) the angle of glare, or the angle that the line joining the eye to the object being looked at makes with the line joining the eye to the object producing the glare; (3) the distance from the eye to the object producing the glare; (4) the extent of the surface of the object producing the glare; (5) the contrast of the brightness of the surface of the object producing the glare with the brightness of the surface being looked at; and (6) the time of exposure of the eye to the object producing the glare.

Since the injurious action of glare depends largely upon the persistence of its effect on the retina, a rough measure of glare may be made by looking steadily at the bright object for 10 seconds, and then closing the eyes and noting the length of time during which the recurring after-images persist.

To avoid glare from the units used for lighting, the light should be indirect, or, if for economic reasons direct lighting must be used, the brightness of the globe inclosing the light should be low at every point of its surface. Surface brightness may be measured in lumens [5] per square foot, in candles per square inch, or in lamberts.[6] Since a lambert is a very large unit, it is usually convenient to measure it in millilamberts, a millilambert being one-thousandth of a lambert.

RATIO OF THE SURFACE BRIGHTNESS OF THE UNITS TO THE ILLUMINATION PRODUCED BY THEM.

In these investigations and tests the measure of the glare effect due to the different units investigated and tested was taken to be the ratio of the average surface brightness of the lighting units to the illumination produced by them on the horizontal working plane, 45 inches above the floor, both being measured in lumens per square foot. The work of Nutting [7] indicates that to make the glare negligible, the ratio of the surface brightness of the unit to the brightness of the objects being looked at must not be too great. For instance, he found that when the eye had become adapted to a brightness of 10 lumens per square foot, a brightness 350 times as great produced distinct discomfort. The values obtained for the ratio of the brightness of the unit to the illumination produced, for the different units inevstigated, are shown in the next section, in Table XXVIII. It will be noted that the brightness of the surface of the globe in-

[5] A lumen is the quantity of light falling upon an area of one square foot, all points of which are one foot distant from a source having an intensity of one standard candle.
[6] A lambert is a lumen per square centimeter.
[7] Trans. Illuminating Engineering Society, Vol. 11, p. 944, and Vol. 15, p. 536.

creases with the wattage of the lamp within it, but that the ratio of brightness to illumination remains about the same for a given unit when installed in any particular place, and also, that for the installations in the City Hall post office the mean ratio was about 67 to 1 both for unit No. 1 and unit No. 2. For the installations in the general post office the mean ratios were approximately 113 to 1, 106 to 1, and 140 to 1 for units No. 2, No. 3, and No. 4, respectively. The value for this ratio for bare lamps is very large, and therefore bare lamps should never be used anywhere in the field of vision.

The illumination on the horizontal working plane will evidently vary with the number and spacing of the units; but the brightness of the surface of a unit will depend only upon the way in which the light emitted by the lamp within it is distributed over its surface, and upon the number of lumens emitted by the lamp. The ratio of the average brightness of the surface of any one of the units to the illumination produced by them will therefore depend upon the number and spacing of the units used. If this ratio is too great in any particular case, it may be reduced either by increasing the number of units used or by decreasing the surface brightness of each of the units. The latter method of reduction may, in general, be accomplished by increasing the surface of the unit, which, in practice, is done by using a unit of larger diameter.

Price,[8] quoting Prof. L. Weber,[9] of Kiel, states that the ratio of the intrinsic brightness of the surface of the lighting unit to the brightness of the surroundings should not exceed a value of about 100 to 1. Weber gives his reason for adopting the ratio of 100 to 1 as follows: "The number 100 is founded upon the conditions prevailing in a normal interior illuminated by light from a blue sky. Under such conditions I assume that the eye will not be dazzled when the gaze is turned away from the interior of the room and directed toward the sky. Now, the intrinsic brilliancy of the sky is about * * * 0.25 primary units. The intrinsic brilliancy of the white surfaces illuminated by the sky in the room under these circumstances will usually be about 0.0025 primary units * * *. The ratio of this to the former quantity is just about 100."

Since the brightness of objects for a given illumination is a very indefinite quantity, on account of their varying coefficients of reflection, it has seemed better in this study to take the ratio of the brightness of the surface of the units to the illumination produced by them as a measure of the glare effect, rather than to attempt to determine the ratio of the brightness of the units to the mean brightness of the objects looked at. The value of the illumination on any surface will always be greater than the value of its brightness, since

[8] The Modern Factory, John Wiley & Sons, Inc., 1914, p. 241.
[9] The Illuminating Engineer (London), 3, 1910, p. 116.

the coefficient of reflection is always less than unity. Most of the envelopes and wrappers handled in the post office are white in color, but many are of other colors, such as red, brown, green, and blue, and the coefficients of reflection vary from about 80 to 50 per cent. The ratio of the surface brightness of the units to the brightness of the objects looked at will therefore always be greater than the ratio of the surface brightness of the units to the illumination of the objects looked at, being, in general, for post office work, from two to one and a quarter times as great. If, for instance, brown, green, or blue envelopes that are being sorted, have a coefficient of reflection of 50 per cent, while the ratio of the brightness of the units to the illumination is 100 to 1, the ratio of the brightness of the units to the brightness of the envelopes will be 200 to 1. It is therefore believed by the investigators that, in view of the opinion expressed by Weber, already referred to, and in view of the values for the ratio of brightness to illumination given in Table XXVIII, which have been found in these tests to represent fairly comfortable working conditions, the ratio of the brightness of the surface of the units to the illumination produced by them should be for comfortable working not greater than 100 to 1.

LIGHTING METHODS.

No attempt will be made in this bulletin to discuss the theories and the advantages and disadvantages of the various lighting systems. Such brief information regarding lighting methods is given as will be sufficient to give an understanding of the reasons for the acceptance or rejection of any single lighting method. At the present time three general systems of lighting are recognized in the art of illumination: First, indirect; second, semi-indirect; and third, direct.

INDIRECT LIGHTING.

In the indirect system none of the light passes from the source directly to the surface illuminated, but is reflected to the latter from other surfaces, such as the ceilings and walls. The source of light is hidden. Where diffused light is necessary, this system is most desirable. It requires, however, that the ceilings and walls should be of a mat surface and of a light color, so as to have good reflecting power without glare. It is evident, then, that the ceilings and walls will require frequent cleaning and painting in order to maintain their reflecting power. The coefficient of utilization [10] of indirect lighting is low, even under ideal conditions.

[10] The coefficient of utilization is defined as the ratio of the total light falling on the working plane to the total light emitted by the bare lamps within the globes or reflectors.

SEMI-INDIRECT LIGHTING.

In the semi-indirect system part of the light from the source passes directly to the surface illuminated, while the remainder is reflected from secondary surfaces. This system of lighting does not depend so much upon the walls and ceilings as does the indirect lighting system, since the bowl, which is opaque in the indirect system, is in whole or in part translucent in the semi-indirect, and part of the light is transmitted directly to the working plane.

DIRECT LIGHTING.

In the direct system of lighting the light proceeds directly from the unit to the working plane. However, on account of the fact that light is emitted by the unit to a greater or less degree in all directions, the ceilings and walls, especially with certain types of units, continue to play an important part in the illumination of the working plane.

COST OF INSTALLATION AND MAINTENANCE.

Cost of installation, cost of maintenance, and other economic factors must be considered in recommending any change in the system of lighting. Among these factors must be included the expense of rewiring, the making of new outlets, the repainting of walls and ceilings in suitable colors, the maintenance of the personnel necessary to keep the walls and ceilings clean, as well as the cost of new fixtures. The post offices are, of course, already wired and illuminated, and so in selecting a new type of lighting, preference should be given to one which would require the fewest changes in the present system. In the cost of maintenance must also be considered the fragility of the units, the rapidity with which they gather dust, the trouble involved in cleaning them, and the frequency with which the walls and ceilings will need cleaning or painting. In respect to these considerations, indirect lighting systems are more costly to maintain than direct systems, because the fixtures are usually open and gather dust and dirt rapidly, and must be cleaned frequently. They are difficult to clean because most of the dirt accumulates inside the bowl. The same statements may be made, in general, in regard to the semi-indirect lighting systems, but probably not so much care need be given to the ceilings and walls in the semi-indirect systems as in the indirect. The closed direct lighting systems are the easiest to keep in good condition. They are more easily cleaned and the walls and ceilings do not require so much attention as in the other systems.

RELATIVE MERITS OF GENERAL AND LOCAL LIGHTING.

A distinction must be drawn between general and local lighting. In general lighting, the units are so placed as to distance apart and as

to height above the working plane and are of such power that they give a more or less even distribution of the required illumination all over the working plane. Local lighting is produced by single units, so placed that they produce illumination over only small areas; they are illustrated by desk lights and by bracket lights over separation cases. Good practice to-day indicates that local lighting should not be used regularly, but only temporarily in emergencies and for very special purposes. General lighting gives a higher illumination for the same number of watts used, and is therefore more economical, because a small number of high wattage lamps are used rather than a large number of low wattage lamps. High wattage lamps produce more light per watt than low wattage lamps.

At the present time the letter separation cases in the general post office and the desks in the offices are illuminated by local lights. There are about 1,150 outlets on the cases and 300 in the offices. In each outlet there is a 15-watt lamp. From Table XXVII it may be seen that it would take ten 15-watt lamps to give as much light as one 100-watt lamp. But ten 15-watt lamps would cost $2.10 as compared with 66 cents for one 100-watt lamp. And so it would cost three times as much for the lamps alone to use 15-watt lamps as it would to use 100-watt lamps, assuming that both wear out at the same rate. Therefore, installation costs, replacement costs, and cost of maintenance are all lower for general lighting than for local lighting. Moreover, general lighting gives more uniform illumination. It is, then, evident that general lighting with a small number of large units is to be preferred to local lighting with a large number of small units. It is sometimes asserted that sufficient illumination can not be obtained in a given place without the use of local lighting, as for instance in front of the separation cases; but modern practice shows that this is not true, and that the same degree of illumination may be obtained at no greater cost by a system of general lighting, which has the advantage that it illuminates not only the given place but its surrounding areas.

TABLE XXVII.—*Output, lumens per watt, number used per year, cost per lamp, and number of outlets, for lamps of different wattages used in the general post office.*

Watts.	Output in lumens.	Lumens per watt.	Number used per year.	Cost of lamp.	Number of outlets.
15	125	8.32	2,065	$0.21	1,150
25	226	9.04	760	.21	926
40	372	9.31	1,114	.21	631
50	480	9.59	2,346	.21	1,640
75	865	11.53	2,709	.42	1,717
100	1,260	12.57	950	.66	569
200	3,100	15.51	313	1.26	146

CHOICE OF METHOD OF LIGHTING.

Taking into consideration the actual conditions which must be dealt with in the Post Office Department and in the post offices themselves—first, that cost of installing systems and maintenance must be carefully taken into account, since the appropriations made by Congress for lighting are always limited to what is thought compatible with economy; second, that the walls and ceilings are in most instances dark in color or dirty or liable to become dirty, and that constant care is required to maintain them in good condition as reflecting surfaces giving the full utilization of light; third, that indirect and semi-indirect systems of lighting require a much greater wattage to give the same illumination, thereby increasing the cost because of the greater amount of current used; and fourth, that not only do the walls and ceilings require frequent attention in the indirect and semi-indirect systems, but the units themselves require constant cleaning—it must be concluded that at the present time the direct system of lighting seems most feasible for post office illumination.

VI. CHOICE OF UNITS FOR POST OFFICE WORKROOMS AND OFFICES.

TESTS TO DETERMINE CHOICE OF UNITS.

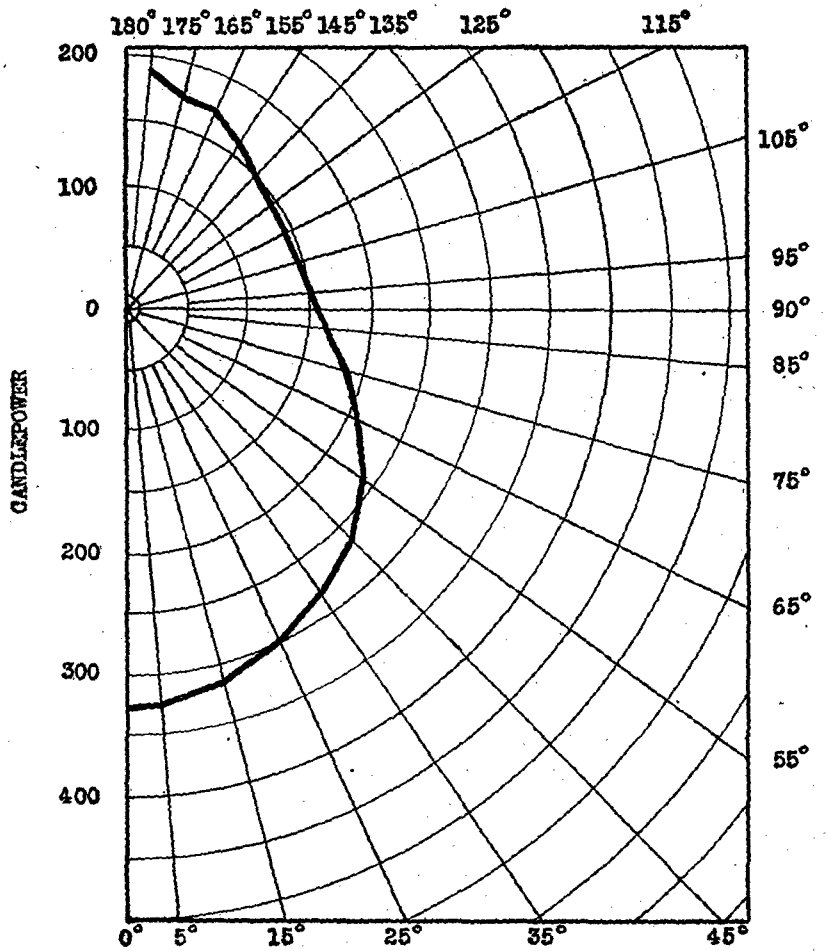
In making a selection of direct lighting units, four fundamental points were kept in mind: First, cost, which must be reasonable; second, efficiency—the unit must give the maximum efficiency, both on the horizontal and the vertical working planes; third, low surface brightness, with a view to reducing glare from the units as much as possible; fourth, shape—the collection of dust on the unit must be reduced as much as possible.

After a survey of the types of units in general use, four units were determined upon to be actually tested by installation in the working areas of the post offices, as fulfilling the fundamental points in view, and as being representative of the different types of units available in the market, and of the best practice in lighting at this time. These units will be referred to as unit No. 1, unit No. 2, unit No. 3, and unit No. 4.

TEST OF UNIT NO. 1.

The distribution curve of unit No. 1 and a table showing the amount of light emitted by the unit through successive zones are shown in Figure 8. It is a completely inclosed unit, made of opal glass in one piece, and roughly drum-shaped, although narrower at the bottom than at the top. The glass is dense at the top, and its contour is designed to increase the downward light. The shape of the unit makes the rate of accumulation of dirt upon it very low and produces an even distribution of brightness over its surface. It is very efficient, about 80 per cent of the light emitted by the bare lamp within it being given out by the unit. It is made in sizes varying in diameter from 9 to 18 inches. The globe of largest size was used in the tests so that the surface brightness might be as low as possible. It may be noted from the table on Figure 8 that about 48 per cent of the light emitted by the bare lamp within the unit is thrown downward and sidewise (between 0° and 90°), and about 32 per cent upward and sidewise (between 90° and 180°). The light going downward and sidewise from it produces a good illumination of both the horizontal and the vertical working planes. Although much of the light going to the upper portions of the walls and ceilings is lost by absorption, some of it is reflected downward and produces a certain amount of diffuse illumination. The light going upward also prevents an undesirable sharp contrast between a brightly illuminated working plane and a dark ceiling. The unit

UNIT NO. 1.



TEST LAMP: Clear Mazda C, 200 Watts, with output of 3,000 lumens.

Zone	Output in lumens	Percent of output of clear lamp
0° - 30°	259	8.6
0° - 60°	861	28.7
0° - 90°	1,453	48.4
90° -180°	962	32.1

FIG. 8.—Distribution curve of Unit No. 1, with a table giving the distribution of its light through successive zones

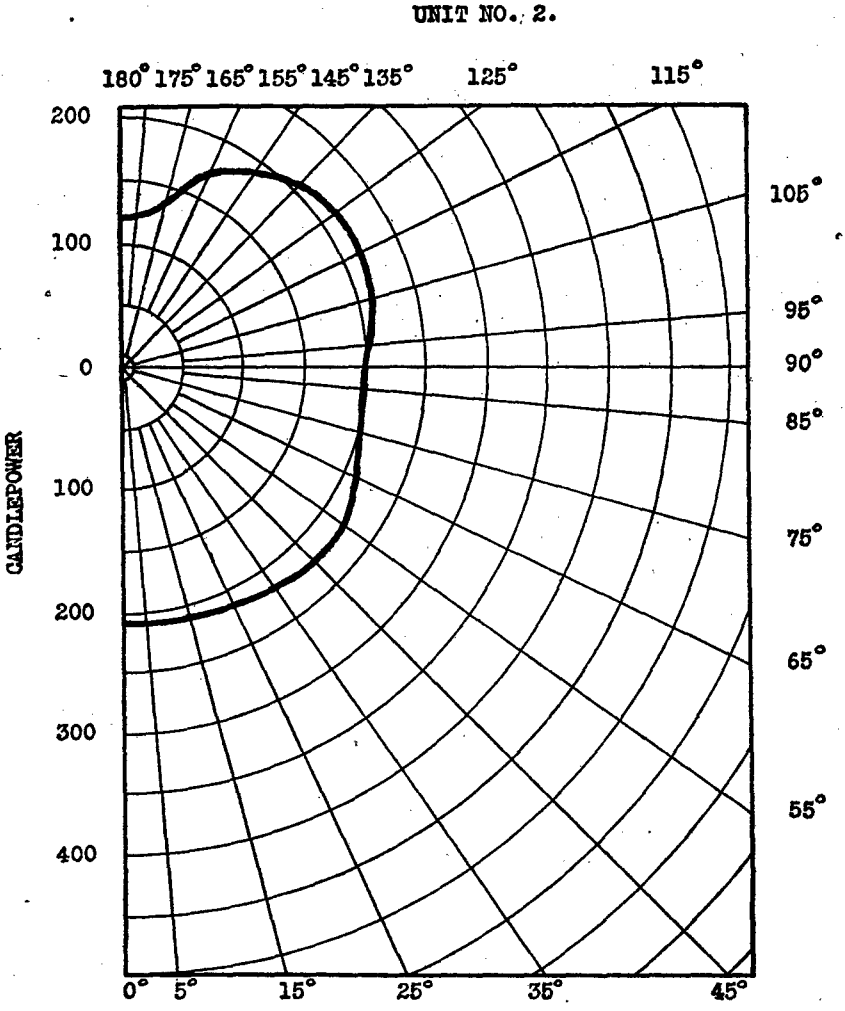
is of reasonable price, very light and easily handled. It differs from some of the cheaper units in the care with which its shape has been designed so as to produce the most desirable distribution of the light and an even distribution of its surface brightness.

This unit was tested with 100, 200, and 300 watt lamps, each placed within the globe so that the filament of the lamp was at the proper point. The tests were made in the third aisle of the letter-separation cases on the mezzanine floor of the City Hall post office in the area marked "1" on plan 1. The conditions in this aisle have already been described. The ceilings were originally buff-colored, but were very dirty when the tests were made, the coefficient of reflection being only 30 per cent. Ten units were installed, arranged in three rows; one row of three units on the west side of the aisle, another row of four units on the east side, the units in the two rows being staggered with respect to each other and the two rows being 6 feet 3 inches apart, and a third row of three units in the middle of the aisle adjacent on the eastern side. The units were hung 10 feet apart in the rows and the filaments of the lamps were 10 feet 6 inches above the floor. On the east side of the aisle, where the measurements of illumination were made, the units were so placed that their centers were 2 feet in front of the face of the pigeonholes. The measurements of illumination were made in front of the separation cases on a horizontal plane 45 inches above the floor and 9 inches out from the face of the pigeonholes. The light illuminating the working plane in front of the separation cases came mainly from the second row of units, since the light from the first row was cut off by the shadow of the observer, and that from the third row by the separation case itself, which was 7 feet high. The results of the tests are shown in Table XXVIII.

TABLE XXVIII.—*Results of tests of lighting units.*

Designation of unit tested.	Diameter of the unit (in inches).	Wattage of lamp used in unit.	Mean illumination on the working plane (in foot-candles).	Mean brightness of unit (in lumens per square foot).[1]	Ratio of brightness to illumination
TESTS AT THE CITY HALL POST OFFICE.					
Unit No. 1	18	100	3.8	230	61:1
Do	18	200	8.3	550	66:1
Do	18	300	14.4	1,060	74:1
Unit No. 2	16	200	6.5	420	65:1
TESTS AT THE GENERAL POST OFFICE.					
Unit No. 2	16	300	7.6	860	113:1
Unit No. 3	16	300	6.0	630	106:1
Unit No. 4	14	200	5.5	810	147:1
Do	14	300	8.2	1,100	134:1

[1] To convert these values into candles per square inch divide by 452.



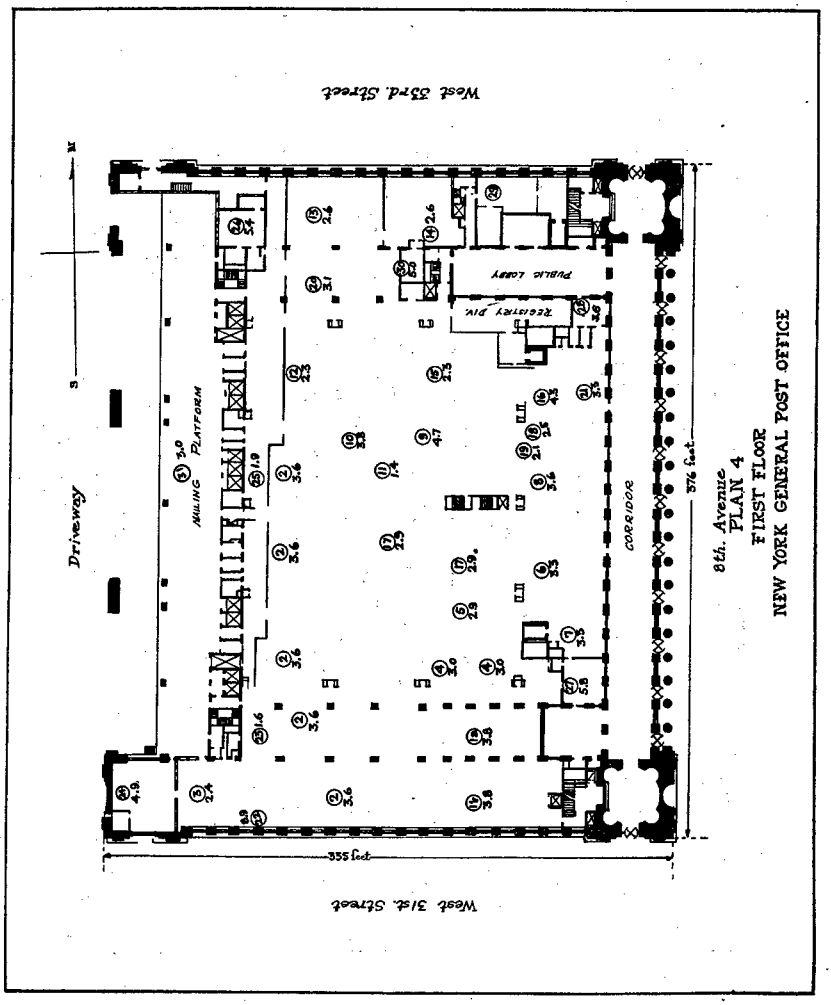
TEST LAMP: Clear Mazda C, 200 Watts, with output of 3,100 lumens.

Zone	Output in lumens	Percent of output of clear lamp
0° - 30°	177	5.7
0° - 60°	683	22.0
0° - 90°	1,323	42.7
90° -180°	1,256	40.5

FIG. 9.—Distribution curve of Unit No. 2, with a table giving the distribution of its light through successive zones

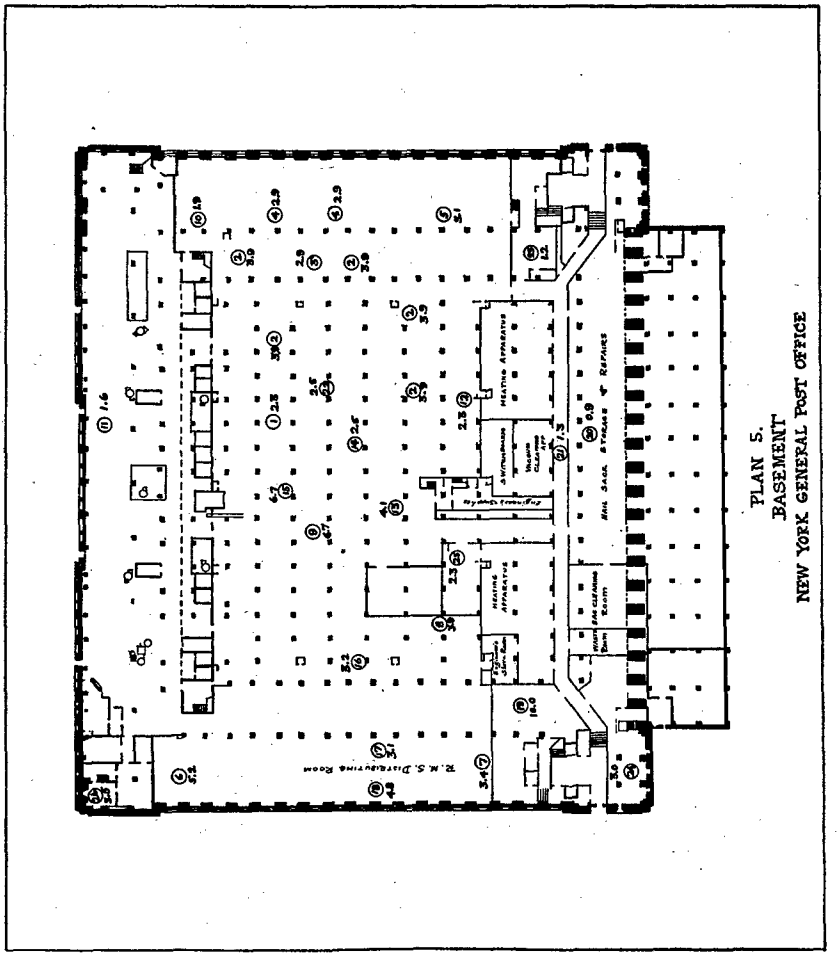
TEST OF UNIT NO. 2.

The distribution curve of unit No. 2 and the amount of light emitted by it through successive zones are shown in Figure 9. The units tested were 16 inches in diameter, the largest size made being used in order to reduce the brightness as much as possible. The



unit is constructed of two layers of glass, one layer of clear crystal and the other of translucent white glass. This method of construction is said to give strength to the unit and to reduce wasteful absorption of the light. The unit is approximately drum-shaped, but is broader at the bottom than at the top. Its shape makes the brightness of its surface low. It may be seen from the table given

on Figure 9 that this unit emits about 83 per cent of the total light given out by the bare lamp within it, and that about 43 per cent of the total light given out by the bare lamp within it is thrown downward and sidewise (between 0° and 90°) and about 40 per cent upward and sidewise (between 90° and 180°). In this unit a large part of the light is purposely sent upward and sidewise so



as to illuminate the ceiling and the upper portions of the walls. For its advantageous use the ceiling and walls must be white or of a light color and clean so that a large part of the light sent upward and sidewise will be reflected down again to produce diffuse illumination on the working plane. It is evident that if the walls and ceilings are not in suitable condition these units can not be used to advantage.

Unit No. 2 was tested both at the City Hall and at the general post office. At the City Hall post office it was tested with a 200-watt lamp within it, under exactly the same conditions as unit No. 1. In the general post office it was tested, with a 300-watt lamp within it, in the parcel-post table area, marked "1a" on plan 4, where 10 units were installed, 13 feet 8 inches apart, with the filaments of the lamps about 12 feet 6 inches above the floor. The ceiling of this portion of the first floor of the general post office is under the mezzanine floor, is vaulted, 16 feet high, light buff-colored, and fairly clean. This area, on account of the vaulted ceiling, was not very suitable for testing indirect or semi-indirect lighting units, but was the most suitable area available. The results of these tests are given in Table XXVIII.

TEST OF UNIT NO. 3.

Unit No. 3 has the same size, shape, and appearance, when not lighted, as unit No. 2, but differs from it in the structure of the glass, which is in three layers, of clear crystal, translucent white, and blue glass, respectively. The distribution of the light is nearly the same for both units, but the light emitted by unit No. 2 simulates sunlight, and that emitted by unit No. 3 the light from the blue sky. Unit No. 3 is not so efficient, as far as the total amount of light emitted is concerned, as unit No. 2, on account of the presence of the layer of blue glass, since it emits only 70 per cent of the light given out by the bare lamp within it. This unit was tested at the general post office in the same place and under the same conditions as unit No. 2. The results of the tests are given in Table XXVIII.

TEST OF UNIT NO. 4.

Unit No. 4, which is a semi-indirect unit, is completely inclosed, 14 inches in diameter, made of prismatic glass, and provided with a removable cover of prismatic glass, which prevents the accumulation of dust and dirt within the bowl. The cover is more or less conical in shape. The lower portion of the inverted bowl is enameled. This unit is very efficient, giving out about 82 per cent of the light emitted by the bare lamp within it. Twenty-three per cent of the light emitted by the bare lamp within it is thrown downward and sidewise (between 0° and 90°), and about 59 per cent upward and sidewise (between 90° and 180°). This unit, therefore, differs from the other units tested, in that it throws a much greater portion of its light to the ceiling and the upper portions of the walls. Since its efficient operation depends upon the character and condition of the

surfaces of the ceilings and walls, those surfaces must be of a proper nature, with high coefficients of reflection.

This unit was tested in the same place and in the same positions in the general post office as were units Nos. 2 and 3. Ten units were installed and were hung so that the bottom of each unit was 11 feet above the floor. They were tested with 200-watt and 300-watt Mazda C lamps. The results of these tests are given in Table XXVIII.

MEASUREMENTS OF BRIGHTNESS.

The measurements of brightness were made with the Macbeth illuminometer. A unit was observed from the side, at a distance of about 10 feet, along a line making an angle of about 70° with the vertical. At this distance the field of the instrument embraced the greater part of the projection of the surface of the unit, and a mean value for the apparent brightness was obtained. The values of the apparent brightness in foot-candles, thus obtained, were then multiplied by 0.845, the coefficient of reflection of the test plate. For each measurement three observations were made, and the mean of all three was taken. The values obtained for the mean brightness are given in lumens per square foot in the fifth column of Table XXVIII. These values may be converted into candles per square inch by dividing by 452. Measurements were also made looking at the unit sidewise and from the bottom, at distances of from 3 to 10 feet, and the means of the results obtained were found to give values of the same order. For instance, for unit No. 2, with a 300-watt Mazda C lamp, the following values for brightness were obtained, looking at different portions of the unit from different distances and at different angles.

	Candles per square inch.
Upper portion of side, 3 feet away, angle 45°	2.28
Lower portion of side, 3 feet away, angle 45°	1.13
Whole side, 10 feet away, angle 70°	2.16
Bottom, 6 feet away, angle 30°	1.95

It may be observed from Table XXVIII that, under the conditions prevailing in the location where the tests were made in the general post office, the brightness of the surface of unit No. 2 and of that of unit No. 3 is lower than the brightness of the surface of unit No. 4; and that the ratio of the brightness of the unit to the illumination produced by it is somewhat lower for unit No. 2 and for unit No. 3 than it is for unit No. 4.

PHOTOGRAPHS.

To aid in the study of the illumination given by the different units under investigation, photographs were taken of the areas

illuminated by the units in the City Hall and general post offices. A No. 3A Autographic Kodak Special camera was used. The exposures were all taken under the light of the units being studied. In most cases six exposures were taken for each picture, the times of exposure being 1, 5, and 30 seconds, and 1, 2, and 3 minutes, respectively. Only the photographs with 2-minute exposures have been reproduced in this report. Rolls of films with six exposures each were used, and usually two rolls were taken of the same subject each time. One roll was developed immediately, and the other was put aside. All the films put aside were later developed in the same bath at the same time and under exactly the same conditions, and all the prints

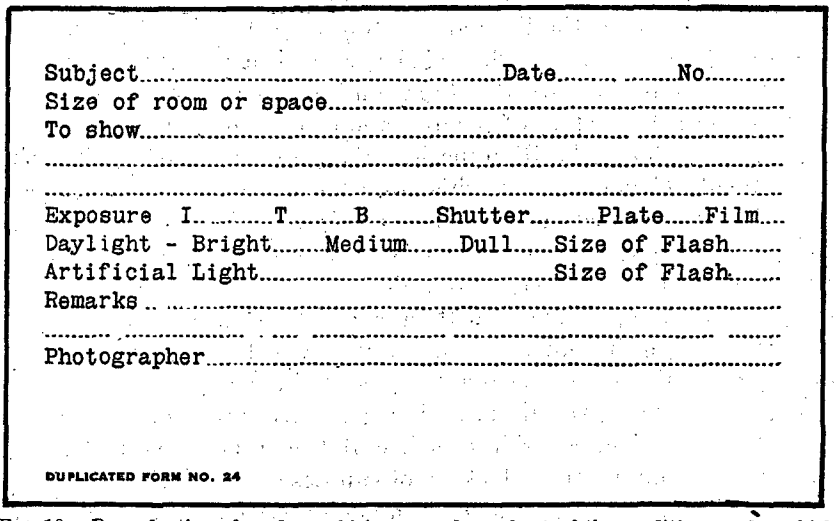

Subject.....Date..... .....No.....
Size of room or space.....
To show.....
.....
.....
Exposure I.....T.....B.....Shutter.....Plate.....Film....
Daylight - Bright.....Medium.....Dull.....Size of Flash.....
Artificial Light.....Size of Flash.....
Remarks .. ..
.....
Photographer.....
DUPLICATED FORM NO. 24

FIG. 10.—Reproduction of card on which a record was kept of the conditions under which each photograph was taken

were made also in the same bath and under the same conditions of time and temperature, in order that the development of all the pictures would be the same, so that the relative brightness and darkness in the photographs and clearness of detail might be used to show the intensity and distribution of the illumination due to a given installation. The opening of the shutter was set at 16 and was the same for all the photographs. A number was given to each photograph, and a record was kept on a card, reproduced in Figure 10.

The photographs were studied and compared to determine the distribution and intensity of the light emitted by the unit.

Figure 11 shows the original lighting installation in the third aisle of the letter separation cases on the mezzanine floor of the City Hall post office. The illumination shown in the photograph was typical of the lighting of the letter separation cases on the mezzanine floor of this post office when this survey was made. Study of the photograph shows that the illumination on both the horizontal

and the vertical working planes was very low, and that the glare from the lighting units was bad. The glare is roughly indicated by the halation of the light around the edges of the units and by the strong contrast between the brightness of the units and the illumination on the ceiling and on the horizontal and vertical working planes.

Figure 12 shows the illumination given by unit No. 1, with 100-watt Mazda C lamps, in the same place. For this installation there was an average intensity of illumination of 3.8 foot-candles on the horizontal working plane. Figure 12 shows a higher illumination of the horizontal and vertical working planes than does figure 11. The photograph also shows that for unit No. 1 the illumination is more uniform over the horizontal and vertical working planes and over the floor and ceiling than for the old unit; and that the glare is less, since the unit has a much larger surface, giving a better distribution of the light and less contrast between the brightness of the surface of the unit and of the surrounding surfaces.

Figure 13 shows the illumination given by unit No. 1 with 200-watt Mazda C lamps. For this installation there was an average intensity of illumination of 8.3 foot-candles on the horizontal working plane. Figure 13, for the 200-watt lamps, shows a much higher illumination of the horizontal and vertical working planes than does figure 12, for the 100-watt lamps. It shows also a good distribution of the illumination on the horizontal working plane and on the vertical face of the pigeonholes of the cases.

Figure 14 shows the illumination given by unit No. 1 with 300-watt Mazda C lamps. For this installation there was an average intensity of illumination of 14.4 foot-candles on the horizontal working plane. The photograph shows a good distribution of the illumination on the horizontal working plane and on the vertical face of the pigeonholes of the cases.

Figure 15 shows the illumination given by unit No. 2 with 200-watt Mazda C lamps. For this installation there was an average intensity of illumination of 6.5 foot-candles on the horizontal working plane.

Figures 15 and 13, for units No. 2 and No. 1, respectively, with 200-watt lamps, show a higher illumination on the floor for unit No. 1, and on the ceiling for unit No. 2, showing that unit No. 1 sends more light downward than No. 2, and No. 2 more light upward than No. 1. Looking at these two photographs, it is seen by contrasting the brightness of the units with the brightness of the surrounding surfaces and by observing the halation at the edges of the units, that the glare from the surface of the units in both cases is small, and that the two units do not differ much in brightness.

Figure 16 shows the illumination given by unit No. 2, with 300-watt Mazda C lamps, installed in the parcel post section of the dis-

Fig. 11.—The original lighting of the letter separation cases in the third aisle on the mezzanine floor of the New York City Hall Post Office, the mean illumination on the horizontal working plane being 2.8 foot-candles

Fig. 12.—Illumination due to unit No. 1, installed on the third aisle of the letter separation cases on the mezzanine floor of the New York City Hall Post Office, with a 100-watt lamp, giving an illumination of 3.8 foot-candles on the horizontal working plane

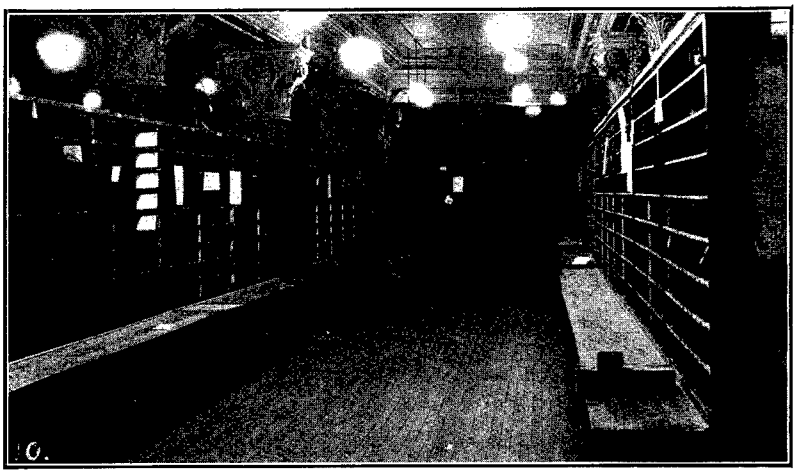


Fig. 13.—Illumination due to unit No. 1 with a 200-watt lamp, giving an illumination of 8.3 foot-candles on the horizontal working plane

Fig. 14.—Illumination due to unit No. 1 with a 300-watt lamp, giving an illumination of 14.4 foot-candles on the horizontal working plane

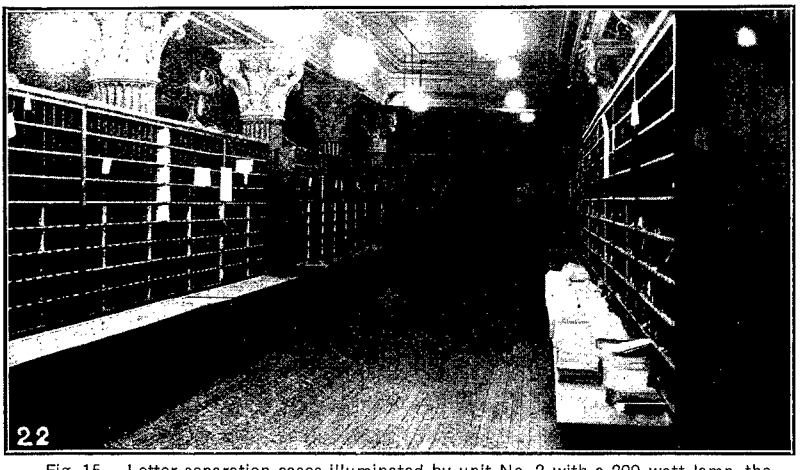


Fig. 15.—Letter separation cases illuminated by unit No. 2 with a 200-watt lamp, the illumination on the horizontal working plane being 6.5 foot-candles

Fig. 16.—Parcel post tables and racks, General Post Office, illuminated by unit No. 2 with a 300-watt lamp, the illumination on the horizontal working plane being 7.6 foot-candles

Fig. 17.—Parcel post tables and racks illuminated by unit No. 3 with a 300-watt lamp, the illumination on the working plane being 6.0 foot-candles

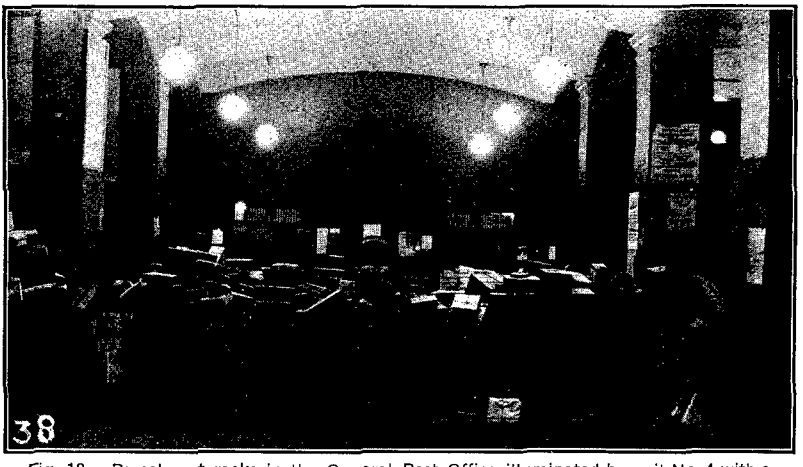


Fig. 18.—Parcel post racks in the General Post Office illuminated by unit No. 4 with a 300-watt lamp, the illumination on the working plane being 8.2 foot-candles

Fig. 19.—Letter separation cases in aisle No. 3 on the mezzanine floor of the New York City Hall Post Office at which the card tests were made, with person in the foreground sorting letters

patching division on the first floor of the general post office. For this installation there was an average intensity of illumination of 7.6 foot-candles on the horizontal working plane.

Figure 17 shows the illumination given by unit No. 3, with 300-watt Mazda C lamps, in the same place. For this installation there was an average intensity of illumination of 6 foot-candles on the horizontal working plane. It may be noted that units No. 2 and 3 produce a high illumination of the upper portions of the walls and ceiling and that, therefore, the lighting by these units is more or less indirect. As has already been stated, unit No. 3 differs from unit No. 2 only in the amount and quality of the light emitted.

Figure 18 shows the installation of unit No. 4, in the same place, with 300-watt Mazda C lamps. For this installation there was an average intensity of illumination of 8.2 foot-candles on the horizontal working plane. The photograph shows that most of the light is sent upward to the ceiling, causing the illumination to be principally indirect; that there is a good illumination of the horizontal and vertical working planes; that the illumination is diffuse; and that the shadows are weak.

CHOICE OF UNITS.

It may be seen from the measurements recorded in Table XXVIII that the surface brightness of units 1, 2, and 3 is low, and that under the conditions of installation in the City Hall post office—that is, with dirty ceilings and walls—unit No. 1 gives a higher illumination than unit No. 2 on the horizontal working plane when lamps of equal wattage are used. The photographs and the distribution curves for the units show also that the distribution of the light is different for the two units, unit No. 1 throwing more light downward than unit No. 2, and No. 2 throwing more light upward than No. 1. Since, under such conditions as obtain in the general workrooms of the post office, unit No. 1 gives the highest illumination, has a low surface brightness, and has a good distribution of its illumination, and since the light output of unit No. 1 is about the same as the light output of unit No. 2 and greater than that of unit No. 3 while its cost compares favorably with the cost of units of its type and the expense of maintenance of the unit is small, only the outer surface needing to be cleaned, a unit having the characteristics of unit No. 1 is considered to be the most suitable kind of lighting unit for use in the general workrooms of the post office.

Since unit No. 2 has a lower surface brightness than unit No. 1, and in rooms where the walls and ceilings are kept clean would produce an illumination approximating that produced by unit No. 1, a unit having the characteristics of unit No. 2 is considered to be the most suitable kind of unit for the executive offices of the post office.

VII. TESTS TO DETERMINE THE INFLUENCE OF ILLUMINATION ON EFFICIENCY AND PRODUCTION.

CHOICE OF GROUP IN WHICH TO MAKE TESTS.

A decision having been made as to the type of unit to be recommended for use in the general workrooms of the post office, it remained to endeavor to determine the intensity of illumination under which the employees could work most efficiently. Under the conditions existing in the post office, the most effective means of determining this intensity seemed to be through a test of the speed and accuracy of a group of workers under different intensities of illumination. The work of the letter separators at the primary separation cases in the dispatching division is one of the most important activities of the post office, not only because of the large number of employees in this occupational group, but also because of the high degree of intensity of the eye work required; and this work appeared, therefore, to be best suited to the conduct of these tests. Moreover, in this group there was a set of conditions giving the fewest variables with which to contend in carrying out the tests; the flow of mail could be kept even; there was a minimum number of separations, 34 in all; the workers had reached and maintained maximum efficiency at these particular cases; and the cases themselves were of such size as to require a minimum amount of physical activity.

DESCRIPTION OF SEPARATION CASES USED IN TESTS.

The three cases selected for these tests were in the third aisle of the letter-separation cases on the mezzanine floor of the City Hall post office, in the area marked "1" in plan 1, where the tests on lighting units, described in the preceding section, were made. In each case there were seven pigeonholes in a horizontal row and nine in a vertical.

The individual holes were about 4¼ inches wide by 5½ inches high, making the total surface area of the case 34 inches wide and 52 inches high. In each case only the lower 34 holes were in use. The cases rested on a table 25 inches high, which brought the bottom of the lowest row of pigeonholes 26 inches above the floor and the bottom of the top row of holes used about 52 inches above it. The table top extended 15 inches in front of the case and formed a shelf upon which the unsorted letters were placed. The cases were constructed of light-colored wood, finished in natural colors, and the pigeonholes

were backed with half-inch wire mesh screening. The cases used for the tests were three of those shown in the row of cases in Figure 19. The person shown in this picture is standing in front of one of them.

POSTURE OF THE WORKERS.

The posture of the worker was usually erect, with head inclined slightly forward and forearms brought to an approximately horizontal position. A slight but only momentary stoop was required for the taller workers to reach the mail on the table. The horizontal working plane was approximately 45 inches above the floor. The workers customarily stood against the edge of the table, holding the mail from 6 to 10 inches in front of the vertical face of the case. The posture of a letter separator is illustrated in Figure 19.

ILLUMINATIONS UNDER WHICH THE TESTS WERE MADE.

Five series of tests were made, under five known intensities of illumination. The first was under the original lighting installation, giving at the cases where the tests were made an average intensity of illumination of 2.8 foot-candles on the horizontal working plane. Ten direct lighting inclosing units of the type of unit No. 1, 18 inches in diameter, giving a fairly uniform distribution of the illumination on the horizontal working plane were then installed in the positions described in the preceding section. Three series of tests were then made under this installation, with successive mean intensities of illumination of 3.6, 8, and 14 foot-candles, obtained by inserting in the units 100, 200, and 300 watt Mazda C lamps, respectively. The units of unit No. 1 type were then removed, and the original installation was used for a fifth test, which served as a check on any possible increase in speed due to acquired familiarity with the tests. Each series of tests covered a period of about 10 days, during which time the illumination remained unchanged.

SELECTION OF SUBJECTS FOR THE TESTS.

In selecting subjects for the tests, three main points were considered: First, familiarity with the test cases used; second, vision; and third, personal qualifications. From the workers at the primary separation cases three groups were selected according to their range of vision without glasses, as follows: (1) Those having vision of 20/20 in both eyes, with no defects nor diseases; (2) those having vision of 20/20 partly, to 20/30, with no abnormalities except errors of refraction; (3) those having vision of 20/30 partly, to 20/40, with no abnormalities except errors of refraction. For convenience, these groups will hereafter be referred to as vision groups A, B, and C, respectively. From these groups a further selection was made, to eliminate persons of highly nervous temperament, unconscientious persons, and those whose records showed much sickness

or any other conditions which might introduce unnecessary variables into the test. After this process of selection and elimination, there remained six subjects in Group A, two in Group B, and four in Group C. In Tables XXIX, XXX, and XXXI Groups A, B, and C have been considered separately, but in Tables XXXII and XXXIII Groups B and C have been consolidated, so that Group 1 represents six employees with normal vision, and Group 2, which is a combination of Groups B and C, represents six subjects with defective vision.

INSTRUCTIONS TO SUBJECTS.

The 12 subjects finally selected were brought together with the investigator who conducted the tests, and a full explanation of the tests was made in order to dispel any possible fear of the relationship of the tests to their post-office records and to relieve any tension which might exist. The subjects were requested to avoid, as far as possible, any spirit of competition among themselves or any ambition to break their own records, and to take each test as an effort apart from the others, giving to each test the best they could do at the time. They were not at any time during the tests informed as to their individual or relative speeds. They were individually requested to live normally during the test period and to report any illness or irregularity which they felt might influence their work on any particular day.

DURATION AND CHARACTER OF THE TESTS.

The immediate object of each test was to determine the speed and accuracy with which each worker could separate 1,000 mat white cards of even thickness and size, 6 by 3½ inches, all clearly addressed in black typewriting, with such address and in such arrangement that each pigeonhole would receive the same number of cards, but that no regular order would prevail, nor would any two cards fall in any hole consecutively.

Three subjects were tested each day, and each subject was given two tests, and only two, under each illumination. All tests were made between 12 noon and 4 p. m., covering the first half of the subject's tour or day's work. Beginning at noon the subjects worked from 20 to 30 minutes upon the regular mail separation at the cases at which they were to take their tests. This work not only enabled their eyes to become adjusted to the illumination, but gave them time to become accustomed to the cases. A thousand cards were then placed in front of each worker, and the first daily test began without an intervening rest period. Time for each subject was taken with a stop watch. Immediately after the conclusion of the first test the workers shifted positions or worked with the investigator in deter-

mining the number of errors made by each worker. The subjects selected for these tests were so familiar with the cases that they seldom had to look at the pigeonholes. This fact made it advisable to separate the errors into mechanical errors and eye errors, the former including all such as placing a card in a box adjoining its proper place, and mixing those in which there was no similarity, such as *Me.* and *Mo.*, in the addresses, while the eye errors included all others. Immediately upon the completion of this determination of the errors, the subject resumed work upon the regular mail separation at the same cases and continued it until 3.25 p. m., when the second test was conducted in the same manner as the first. Time spent away from the case during the entire four hours was recorded for any period over five minutes.

RESULTS OF TESTS.

As already stated, 6 workers were selected for the tests in the A group, 2 in the B group, and 4 in the C group—a total of 12 in all. It would have been better to have had a larger number of subjects in each group, and to have made a larger number of tests with each individual under each degree of illumination. It would further have been desirable to have made another series of tests with the same individuals at periods of time covering several months after they had completed their final test under the original degree of illumination. Circumstances over which the investigators had no control, however, limited the number and character of the tests. No definite conclusions can be derived from the results of the tests, but it is felt that because of their evident consistency the data presented in Table XXIX are of value in indicating the trend of these tests. They must be regarded as being more or less of an experimental nature, and their major importance has been in suggesting methods to be used in additional studies which are being carried on by the service.

TABLE XXIX.—*Average time in minutes, for all individuals, in each group, taken to sort 1,000 cards under different illuminations.*

Illumination in foot-candles.	A Group (6 persons).			B Group (2 persons).			C Group (4 persons).		
	First test.	Second test.	Difference between first and second tests.	First test.	Second test.	Difference between first and second tests.	First test.	Second test.	Difference between first and second tests.
2.8	19.32	19.22	+0.10	18.63	19.21	−0.58	21.99	22.01	−0.02
3.6	18.12	17.71	+.41	16.21	15.79	+.42	18.02	18.11	−.09
8.0	16.74	16.32	+.42	15.34	14.83	+.51	17.24	17.54	−.30
14.0	17.14	16.71	+.43	15.61	14.90	+.71	17.09	16.67	+.42
28	17.76	17.25	+.51	16.33	15.93	+.40	17.77	17.75	+.02
Mean difference			+.37			+.29			+.01

Table XXIX gives the average time of sorting for each group during the first and second tests, under different degrees of illumination. Certain factors probably enter into all these tests: First, an increase of production due to better illumination; second, an increase of production due to experience with the cards; third, an increase of production due to the fact that the operator knew he was undergoing a test; and fourth, a decrease of production due to fatigue of either the body or the eyes. It is natural to expect that in the repeated performance of any work there will be a gradual increase in efficiency due to experience. It is also reasonable to believe that, if these tests were repeated at short intervals, the gain in efficiency would probably be greater than if they were repeated at longer intervals. Although the conditions of the tests were explained as fully as possible to all the workers, it was naturally to be expected that the first test would take the longest time, since the workers were not quite familiar with the size and feel of the cards, and were not quite sure that they would all be addressed in the same way. After the early tests the elements of uncertainty, to whatever extent they may have been present, had been definitely eliminated.

Collis and Greenwood[1] have given four curves indicative of the hourly output of workers engaged in different work processes. The B curve, which they have designated as the curve for light monotonous work, descends during the first hour of work and then remains nearly horizontal during the second, third, and fourth hours; the C curve, designated as the curve for light dexterous varied work, rises abruptly during the first hour of work, remains practically horizontal for the next two hours, and falls during the fourth hour of work. The character of post office work, while it is light and monotonous, is somewhat varied, so that it is likely that the output curve for the post office would fall in between these two curves, probably showing an increase in production during the first hour and a slight falling off, or little or no change, in production during the second, third, and fourth hours. From Table XXIX it is clear that in the A group the second test was performed at a more rapid rate than the first test under all degrees of illumination. In the B group, under 2.8 foot-candles, the work was performed more rapidly in the first test than in the second. In the C group the work was performed more rapidly in the first test than in the second, under 2.8 foot-candles, 3.6 foot-candles, and 8 foot-candles. It would seem, therefore, that to a certain extent under the lower illuminations the two defective-vision groups show greater fatigue than the normal-vision group, and that, in a general way, these two groups show less fatigue as the illumination is increased. This

[1] Collis and Greenwood, The Health of the Industrial Worker, 1921, p. 94.

point seems to be borne out still further by the fact that, when the groups were returned to the original illumination at the end of the tests, the two defective-vision groups again tended to show less difference between their output in the first and second tests of the day; this being especially true of the poorest-vision, or C group, in which the work was performed approximately in the same time for each test.

In a general way all the groups increased their production as the illumination increased. The A group and the B group, however, reached their maximum production under an illumination of 8 foot-candles. The poorest-vision, or C group, reached its greatest production under 14 foot-candles. This may be taken as an indication that higher illumination is needed by defective-vision groups. The difference between the lowest and the highest time of sorting in each group is seen to be 3 minutes for the A group, 4.38 minutes for the B group, and 5.34 minutes for the C group. This greater improvement in speed in the B and C groups seems to indicate that the good-vision group has, even under poor illumination, a speed somewhat nearer its maximum than have the poorer-vision groups, and that with increased illumination the three groups tend to approach each other in speed. This table indicates that, in each of the groups, when the workers repeated the test under the original illumination they shortened the time of the test. This fact, together with the fact that the groups contained so few workers, makes it extremely difficult to determine exactly what increase in efficiency actually occurred because of increased illumination. The physical condition of the workers, the character of the weather, the day of the week upon which the tests were performed, all may have had some bearing on the results. Nor is it known at the present time whether these workers would not have gradually returned to their original speed of production if they had been allowed to continue under the original illumination for a longer period of time. In Table XXX the mean performance for both tests of each individual in each group under each degree of illumination is given; and in Table XXXa each worker has been graded with an index number of 100, representing the time taken to sort 1,000 cards under the original illumination of 2.8 foot-candles. Here again it is evident that, as pointed out in the previous table, the variation from the original time of sorting is least for the subjects in the good-vision group and greatest for those in the poorest-vision group, and that the subjects in the poorest-vision group reach their maximum efficiency under the greatest degree of illumination. In regard to the failure, in each instance, of the groups and individuals to return to their original production after the tests were completed, the fact

was noted in a similar experiment in England in regard to coal production.[2] When the coal miner used an ordinary lamp, the production was 2.47 tons; with a lamp six times as bright, it was 2.83 tons, an increase of 14.6 per cent. When the miner returned to the use of the ordinary lamp, the production did not return to its original value but still remained 5.4 per cent above it.

TABLE XXX.—*Average time in minutes, for both tests, taken to sort 1,000 cards for each individual in each group under different illuminations.*

Vision group.	Designation of individual.	Average time.				
		2.8 foot-candles.	3.6 foot-candles.	8 foot-candles.	14 foot-candles.	2.8 foot-candles.
A	1	17.19	15.94	13.50	14.26	15.82
	2	23.18	19.46	17.70	18.88	19.50
	3	19.59	18.86	17.90	17.83	18.53
	4	23.24	21.73	20.15	19.46	20.78
	5	17.39	16.40	15.55	16.68	16.58
	6	15.05	15.09	14.37	14.38	13.74
B	7	15.69	13.76	13.64	13.46	14.51
	8	22.15	18.24	16.52	17.05	17.75
C	9	20.23	16.74	16.77	15.56	17.61
	10	27.88	20.93	19.54	18.73	18.92
	11	20.91	18.22	17.62	17.98	18.16
	12	18.98	16.38	15.64	15.26	16.34

TABLE XXXa.—*Average time in minutes, for both tests, taken to sort 1,000 cards, for each individual in each group, under different illuminations, reduced to index numbers.*

Vision group.	Designation of individual.	Index numbers.				
		2.8 foot-candles.	3.6 foot-candles.	8 foot-candles.	14 foot-candles.	2.8 foot-candles.
A	1	100	92.7	78.5	82.9	92.0
	2	100	83.9	76.4	81.4	84.1
	3	100	96.3	91.4	91.0	94.6
	4	100	93.5	86.7	83.7	89.4
	5	100	94.3	89.4	95.9	95.3
	6	100	100.3	95.5	95.5	91.3
	Average	100	92.9	85.8	87.8	90.8
B	7	100	87.7	86.9	85.8	92.5
	8	100	82.3	74.6	76.9	80.1
	Average	100	84.6	79.7	80.6	85.3
C	9	100	82.7	82.9	76.9	87.0
	10	100	75.1	70.1	67.2	67.8
	11	100	87.1	84.3	86.0	86.9
	12	100	86.3	82.4	80.4	86.1
	Average	100	81.6	78.5	76.2	80.2

[2] Farmer, Adams, and Stephenson, An Investigation in a Coal Mine (II): Journal National Institute of Industrial Psychology, vol. 1, pp. 173–181, 1923.

TABLE XXXI.—*Average speed (number of cards sorted per minute) for both tests under different illuminations.*

Group.	Number of cards sorted per minute.				
	2.8 foot-candles.	3.6 foot-candles.	8.0 foot-candles.	14.0 foot-candles.	2.8 foot-candles.
A	51.8	55.8	60.4	59.1	57.1
B	52.8	62.5	66.3	65.5	61.9
C	45.4	55.3	57.5	59.2	56.3
Mean for groups B and C combined	47.6	57.5	60.1	61.2	58.0
Mean for groups A, B, and C combined	49.7	56.6	60.3	60.1	57.6

In Table XXXI, instead of using the average time in minutes of sorting 1,000 cards, the average number of cards sorted per minute has been taken. The speed is shown separately for each of the Groups A, B, and C; for the Groups B and C taken together; and for the Groups A, B, and C taken together. From Table XXXI Table XXXII has been derived, to show the percentage increase in speed for each degree of illumination over the speed shown in the original test under 2.8 foot-candles. The mean gain for the normal

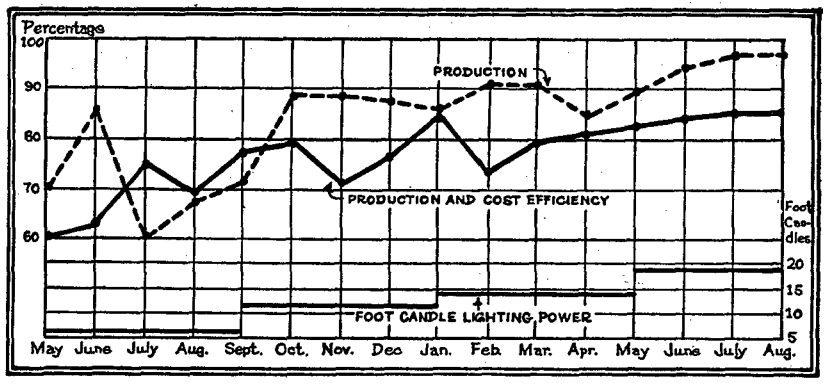


FIG. 20.—Results of tests conducted by the Detroit Piston Ring Co. on the relation of production to illumination

group under 8 foot-candles is 16.6 per cent, and the mean gain for the subnormal group under this illumination is 26.2 per cent. The mean gain for both groups, weighted according to the percentage of normal and subnormal vision [8]—namely, 17.1 per cent and 82.9 per cent, respectively—found in the postoffice workers examined, is 24.6 per cent. If the results obtained for the groups when they were returned to their original illumination were discarded it might be considered that the increase in illumination for these workers from

[8] See values given in Table XVIII for percentages of normal vision in both eyes with no defects.

2.8 foot-candles to 8 foot-candles resulted in a mean gain of speed of 24.6 per cent. It is not felt, however, that this percentage can be taken as representing the final and ultimate gain in efficiency. While it does represent the actual increase in efficiency of the group when working under 8 foot-candles over that when working under 2.8 foot-candles during these tests, the investigators are not sure that part of this gain in efficiency may not have been due to familiarity with the cards, nor that the gain would have continued over a long period of time. Figure 20 is taken from "Factory,"[4] for February, 1923, and represents the experience of the Detroit Piston Ring Co., in one of its shops over a period of 15 months. Its experience would seem to indicate an increased production occurring simultaneously with increased illumination, without a tendency to return to the original production. In Table XXXIII the basis was the speed of the two groups in the final tests on return to the original illumination, and from this speed the percentage gain in speed for each group under each degree of illumination was calculated. From this table it was found that the mean gain for both groups under 8 foot-candles, weighted according to the percentage of normal and subnormal vision found among the post-office employees examined, is 4 per cent.

TABLE XXXII.—*Percentage increase in speed of sorting 1,000 cards for different illuminations over that for the original illumination of 2.8 foot-candles.*

Group.	Percentage increase.				
	2.8 foot-candles.	3.6 foot-candles.	8.0 foot-candles.	14.0 foot-candles.	2.8 foot-candles.
Group A, normal vision	0.0	7.8	16.6	14.1	10.2
Groups B and C combined, subnormal vision	0.0	20.8	26.2	28.4	21.8
Groups A, B, and C combined and weighted according to the percentage of normal and subnormal vision in post-office employees	0.0	18.6	24.6	26.0	19.8

TABLE XXXIII.—*Percentage change in speed of sorting 1,000 cards for different illuminations over that for the final illumination of 2.8 foot-candles.*

Group.	Percentage change.				
	2.8 foot-candles.	3.6 foot-candles.	8.0 foot-candles.	14.0 foot-candles.	2.8 foot-candles.
Group A, normal vision	−9.3	−2.3	5.8	3.5	0.0
Groups B and C combined, subnormal vision	−17.9	−0.9	3.6	5.5	0.0
Groups A, B, and C combined and weighted according to the percentage of normal and subnormal vision in post-office employees	−16.4	−1.1	4.0	5.2	0.0

[4] A. W. Shaw Co., Chicago, Ill.

As stated previously, the errors which were made in performing the test were divided into eye errors and mechanical errors. In Table XXXIV the total errors for all the subjects are shown for

TABLE XXXIV.—*The total and the average number of errors per individual, made in sorting 1,000 cards under different illuminations.*

Illumination in foot-candles.	Eye errors.		Mechanical errors.		Total errors.	
	Total.	Average per subject.	Total.	Average per subject.	Total.	Average per subject.
3.6	18	1.50	16	1.33	34	2.83
8.0	4	0.33	19	1.58	23	1.92
14.0	4	0.33	9	0.75	12	1.00
2.8	10	0.83	27	2.25	37	3.08

the various degrees of illumination. It is interesting to note here that the number of errors per subject decreases as the illumination becomes greater, the total number of errors per subject being 3.08 under 2.8 foot-candles, 2.83 under 3.6 foot-candles, 1.92 under 8 foot-candles, and 1 under 14 foot-candles. This reduction in the number of errors may be taken as added proof of what has already been shown—namely, the increase of efficiency in all the groups under higher degrees of illumination.

Briefly summarizing the results of these tests, it may be said that, from the present evidence, there seem to be a definite increase of efficiency and a decrease in the number of errors in letter sorting, with an increase in illumination. The increase in efficiency generally coincident with the increase in illumination seems to be greater for workers with defective vision than for workers with normal vision. The tests seem to indicate that part of this increase in efficiency is due to reduction of fatigue in the workers with poorer vision.

TESTS WITH COLORED CARDS.

The color of envelopes and package wrappers may be an important factor in the speed with which mail is handled. For this reason certain combinations of colors, based upon previous work on color vision,[5] were selected, and colored cards were prepared, of the same size and quality as the mat white cards used in the previously described tests. The combinations selected were black typewriting on a buff card, black typewriting on a mat white card, green typewriting on a mat white card, and red typewriting on a green card.

[5] See Luckiesh, Color and Its Applications, 1921, pp. 136–137.

The colors of the cards and the typewriting were identified as corresponding closely with colors given in the "Atlas of the Munsell Color System."[6] The color of the buff card corresponds most closely to $Y\frac{8}{5}$, on chart 80 of the Munsell system, though it is a trifle redder, shading between $Y\frac{8}{5}$ and $YR\frac{8}{5}$, but nearer to $Y\frac{8}{5}$. The color of the green card corresponds most closely to $BG\frac{5}{5}$, on chart 50, but is of a slightly lighter shade. The color of the red typewriting corresponds closely to $5R\frac{4}{10}$, on Chart H, and the color of the green typewriting corresponds closely to $5G\frac{4}{7}$, on Chart H. The colors of the typewriting also correspond very closely to the red and the green of the Prang color system.

Two subjects, one from Group A and one from Group C, whose color vision had been tested by means of the Holmgren color test and found to be normal, were used in a special series of tests conducted daily in conjunction with the other tests and in the same manner, one set of colored cards being used each day, so that in four consecutive days each subject had completed the series under the particular intensity of illumination. Each subject separated 14,000 cards before the beginning of the actual tests, and attained during the latter portion of these preliminary separations a fairly constant speed. In this way possible variations due to unfamiliarity with the cards were practically eliminated.

A second series of tests was conducted with the same cards and the same subjects, with the addition of another subject from vision Group A. The object of the second series was to test these subjects on all colors under one intensity of illumination on the same day, thus eliminating in each individual the variations that might occur from one day to another. The test was begun at noon, and the subjects worked on regular mail separation, as in the former tests, until their eyes became accustomed to the illumination. Each of them then separated a thousand of the colored cards, records being kept as in the other tests. At the close of this test they leisurely mixed the cards for the next test and then rested 10 minutes before beginning it. This was repeated until each subject had handled the four sets of cards. The order in which the colors were separated by the subjects was different. Both series of tests were made successively under illuminations of 3.6, 8, and 14 foot-candles.

[6] Munsell Color Co., New York City.

TABLE XXXV.—*Average time in minutes taken to sort 1,000 cards for different color combinations under different illuminations.*

Color combinations.	Number of tests made under each illumination.	Time in minutes.		
		3.6 foot-candles.	8 foot-candles.	14 foot-candles.
FIRST SERIES.				
Green on white	4	17.43	17.18	16.35
Black on white	4	18.69	16.52	16.49
Black on buff	4	18.38	16.65	17.11
Red on green	4	19.14	17.30	16.97
SECOND SERIES.				
Green on white	3	19.46	18.09	17.89
Black on white	3	19.05	18.43	18.06
Black on buff	3	19.45	18.98	18.11
Red on green	3	19.89	18.90	18.16

Table XXXV gives the results of these two series of tests with colored cards. There are two facts which seem to be borne out in both series: First, it was found by these tests, as in the previous tests with the white cards, that with all colors there was the same tendency toward increased speed under increased illumination. In all the tests, except when black-on-buff cards were used in the first series, the greatest improvement was found under 14 foot-candles. Second, it was found that in both tests there was a preferential selection of certain combinations of colors, a white background with a green or black ink giving the greatest speed in all tests. The predominating order of the four combinations with respect to decreasing speed was found to be green on white, black on white, black on buff, red on green. It is very interesting to note that this order conforms to the order of preference given by Luckiesh [7] for color combinations most legible at a considerable distance from the eye, with the difference that in his order black on yellow (in this case, buff) was preferred to green or black on white. This difference may be due to the fact that most of the mail handled by the subjects in the present tests has a white background. The total number of eye errors for these colors was checked, as in the previous tests; for the first series of tests, 8 errors occurred in the green on white cards, 7 in the black on white, 6 in the black on buff, and 8 in the red on green; for the second series of tests the total number of eye errors occurred in about the same proportion; namely, 9 in the green on white cards, 7 in the black on white, 5 in the black on buff, and 7 in the red on green. It would seem from the number of errors made that color itself is not an im-

[7] Luckiesh, Color and Its Applications, 1921, p. 137.

portant factor in causing errors, but that, if there is any difference for color, the fewest errors are made with the black on buff cards.

It should be noted that, in making the color tests, the object was to determine whether or not there was any difference in the time necessary to sort cards of different color combinations. While the tests were made under three degrees of illumination, namely, 3.6, 8, and 14 foot-candles, there was no attempt in these tests to determine whether there was any increased efficiency under the higher degrees of illumination. However, in the tabulation of the results of these color tests, Table XXXV, there is shown the time of sorting a thousand cards under three different degrees of illumination. From Table XXXV Table XXXVI has been constructed, giving the number of cards sorted per minute. From this table it may be determined whether or not there was any increase in the number of cards sorted per minute when the illumination was increased from 3.6 foot-candles to 8 foot-candles and 14 foot-candles. In Table XXXVII the percentage increase in speed is given for the tests with colored cards and for the efficiency tests with white cards. It may be noted that the percentage increase in speed in the tests with colored cards, when going from 3.6 foot-candles to 8 foot-candles, was 6.8 per cent; in the efficiency test the corresponding increase was 5.1 per cent. In going from 3.6 foot-candles to 14 foot-candles the percentage increase was 8.8 per cent for the tests with colored cards and 6.5 per cent for the efficiency tests. It is felt that the general similarity of the percentages obtained in the color tests to those obtained in the efficiency tests supports the conclusions deduced from the efficiency tests.

TABLE XXXVI.—*Average number of cards sorted per minute for different color combinations under different illuminations.*

FIRST SERIES.

Color combinations.	Number of tests made under each illumination.	Number of cards sorted per minute.		
		3.6 foot-candles.	8 foot-candles.	14 foot-candles.
Green on white	4	57.4	58.2	61.2
Black on white	4	53.5	60.5	60.6
Black on buff	4	54.4	60.1	58.4
Red on green	4	52.2	57.8	58.9
SECOND SERIES.				
Green on white	3	51.4	55.3	55.9
Black on white	3	52.5	54.3	55.4
Black on buff	3	51.4	52.7	55.2
Red on green	3	50.3	52.9	55.1
Means for all colors and both series		52.9	56.5	57.6

TABLE XXXVII.—*Mean percentage increase in speed of sorting 1,000 cards for different illuminations over that for 3.6 foot-candles, weighted according to the percentage of normal and abnormal vision in each group for white cards and for cards of different colors.*

Character of cards.	Percentage increase in speed.		
	3.6 foot-candles.	8 foot-candles.	14 foot-candles.
Of different colors	0.0	6.8	8.8
White	0.0	5.1	6.5

VIII. ECONOMIC ADVANTAGES OF INCREASED ILLUMINATION.

The actual power consumed in the general post office for lighting during the calendar year 1921 was 1,113,320 kilowatt hours. The cost of this power, based upon the minimum rate per kilowatt hour under the contract with the lighting company, was, for the calendar year 1921, $26,334. The cost of replacing lamps under the present system during the year was $6,587, which makes a total cost of $32,921.

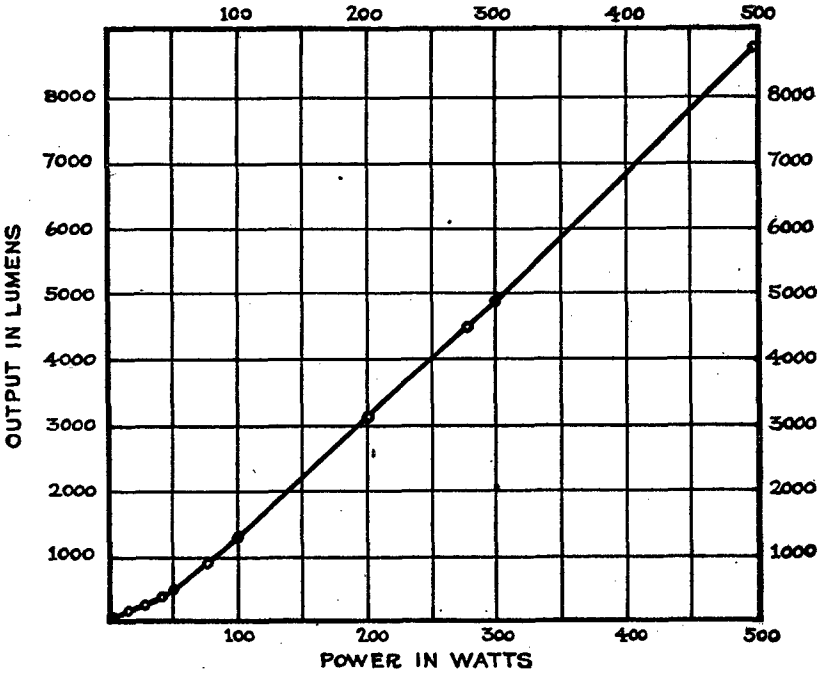


FIG. 21.—Relation of output in lumens to power in watts for Mazda C lamps

With the above-mentioned consumption, the mean illumination in this post office was 3.6 foot-candles. To find out what the consumption of power would be if this illumination were raised to 8 foot-candles, the present consumption must be multiplied by the factor 1.89. This factor is less than that required to multiply the present illumination of 3.6 foot-candles in order to obtain 8 foot-candles,

because the total number of outlets is supposed to remain the same, while the illumination from a lamp increases more rapidly than its wattage.

The value of the factor 1.89 was calculated in the following way. The ratio of the desired illumination, 8 foot-candles, to the present illumination, 3.6 foot-candles, is 2.22 to 1. Therefore the desired output in lumens must be 2.22 times as great as the present output. The output of the Mazda lamps of different wattage used in the post office was taken from Bulletin L. D. 117, second edition, of the Edison Lamp Works of General Electric Co., and was plotted as a function of their wattage in the graph shown in Figure 21. The output of each lamp which had been used in plotting the graph was then multiplied by the factor 2.22, and the wattage necessary to produce this increased output read off from the graph. These values are given in columns 1, 2, 3, and 4, in Table XXXVIII. The ratio of the increased wattage to the present wattage was then found for each case. These values are given in column 5 of the table. It may be noticed that the values of this ratio first decrease and then increase, varying from 2.07 to 1.74 and having a minimum value for the 50-watt lamp. The mean value for the ratio, 1.89, was taken as the factor to be used in the calculation. In making this calculation, the total number of lamps and the relative number of lamps of different wattages were assumed to be kept the same as they are at the present time. This places the estimate on a very conservative basis, since it is highly probable that, in increasing the intensity, larger and fewer lamps would be used, giving more illumination per watt than smaller units and reducing the wattage required.

TABLE XXXVIII.—*Wattage of lamps used in the general post office, their output in lumens, the output multiplied by 2.22, the necessary wattage to give this increased output, and the ratio of this wattage to the original wattage.*

Present wattage.	Output in lumens.	Output multiplied by 2.22.	Increased wattage necessary to give increased output.	Ratio of the increased wattage to the present wattage.
15	125	278	31	2.07
25	226	502	50	2.00
40	372	826	72	1.80
50	480	1,066	87	1.74
75	865	1,920	133	1.77
100	1,260	2,797	182	1.82
150	2,040	4,529	281	1.87
200	3,100	6,882	408	2.04
300	4,840	.....	.....	.....
500	8,750	.....	.....	.....
Mean	.....	.....	.....	1.89

The increased wattage required on this basis would bring the consumption to 2,104,180 kilowatt hours, at a cost of $49,770, and the

cost of replacing the lamps to $12,450, a total annual cost of $62,220. The increase in the cost for the higher intensity of illumination is therefore the difference between $62,220 and the present cost of $32,921, or about $29,300.

The total pay roll for this post office for 1921 amounted to $6,746,039. Since investigation shows that only about one-half the time of the workers is spent under artificial illumination, about one-half of this amount, or approximately $3,373,000, will represent the amount paid to the workers when working under artificial illumination.

One per cent of this sum would be approximately $34,000, so that apparently, as far as the annual cost of power and maintenance is concerned, any gain in efficiency of 1 per cent or more would offset the increase in cost incurred by raising the illumination from 3.6 to 8.0 foot-candles.

It should be borne in mind that an initial outlay for the purchase of new lighting units would be required, and that in certain instances new wiring would be necessary to carry the increased current.

In the summary of this report which was made to the Postmaster General, part of which has been already published, 4.4 per cent was taken as a rather arbitrary figure to represent the increase in efficiency under the increased illumination recommended. This percentage was taken to determine the economic yearly saving for a single post office. The further analysis of the efficiency tests described in the preceding section do not seem, however, to warrant the acceptance of any specific figure as representing the increase in efficiency due to higher illumination. It is believed, though, that the data which have been presented show that an increase of certainly more than 1 per cent in efficiency would result from the higher illumination.

IX. CONCLUSIONS AND RECOMMENDATIONS.

CONCLUSIONS.

The illumination in the post offices studied was found to be low in intensity and unsatisfactory in its distribution, both because of the nature and the spacing of the lighting units used, and because of the lack of their proper maintenance, reflectors frequently being dirty or missing, and bulbs, dirty, old, or missing. Glare is frequently present, shadows are numerous, lights are improperly spaced and improperly located in relation to work, and the intensity of illumination is irregular and unequal. The actual mean illumination in these post offices is generally below that of the requirements of the State codes of lighting and is generally lower than the mean illumination furnished employees doing similar work in private industries.

The number of eye defects and the number of cases of defective vision vary, in a general way, as the wrok processes require increased intensity of eye work, the largest number of defects and the poorest vision being found in the group of workers doing the most intensive eye work.

There seems to be a definite relation between certain diseases of the eye and defects of vision and the amount of illumination under which the workers are occupied. In this respect it was found that the employees at the old post office, the majority of whom were working under an average artificial illumination of 2 to 3 foot-candles, had a smaller percentage of normal vision and a greater percentage of certain eye defects than the employees at the new post office, the great majority of whom were working under all or part-time daylight.

The higher the intensity of illumination, up to a certain point, the greater was the rapidity with which the work was performed. The data collected seem to indicate that less fatigue is experienced under higher illumination, especially in the poorer vision groups.

It is believed that installation of higher illumination would result in a pecuniary saving to the post office, would tend to reduce eye fatigue and the eye defects resulting therefrom, and would conserve the eyesight of the employees.

RECOMMENDATIONS.

The present illumination in the post offices should be changed. There should be installed in the general workrooms and offices sys-

tems of totally inclosing units, of the diffusing or light-directing type, giving a general intensity, when first installed, of 10 foot-candles[1] everywhere on a horizontal working plane 45 inches above the floor, and all local lighting should be done away with.

The lighting unit to be installed in the general workrooms of the post office should be of such quality of glass and of such shape and size that its brightness at any point of its surface would not exceed 2.5 candles per square inch when used with an incandescent lamp or other source of light emitting 3,100 lumens. This unit should have an output of at least 80 per cent of that of the clear lamp and a spherical distribution of its candlepower such that at least 8 per cent of the light emitted by the clear lamp would be emitted by the unit through the zone from 0° to 30°, at least 28 per cent from 0° to 60°, at least 48 per cent from 0° to 90°, and at least 25 per cent from 90° to 180°.

The lighting unit for the offices of the post office should be of such quality of glass and of such shape and size that its brightness at any point of its surface would not exceed 2 candles per square inch when used with an incandescent lamp or other source of light emitting 3,100 lumens. This unit should have an output of at least 80 per cent of that of the clear lamp and a spherical distribution of its candlepower such that at least 5 per cent of the light emitted by the clear lamp would be emitted by the unit through the zone from 0° to 30°, at least 20 per cent from 0° to 60°, at least 40 per cent from 0° to 90°, and at least 35 per cent from 90° to 180°.

The units for both the general workrooms and the offices should be such in number and so spaced that their brightness measured in lumens per square foot would not be more than one hundred times as great as the intensity of the illumination, measured in foot-candles, produced by them on a horizontal plane 45 inches above the floor.

Wire screening should not be used for the back of a separation case, on account of its bad effect upon the eyes. It should be replaced by a continuous surface, or by strips of wood 2 inches wide and one-fourth of an inch apart, so as to allow ventilation.

Employees in the post office should do their work at such places and in such shifts that they would have daylight illumination for as great a portion of their working time as possible. Separation work should not be done in the basement of any post office building, except to meet an emergency. New post offices should be so constructed that as much work as possible may be done under daylight.

The eyes of post-office employees should be examined once a year; any defects found should be recorded, and the employee with a

[1] Ten foot-candles, when first installed, are recommended so as to allow for a deterioration of 20 per cent, which would reduce the illumination to 8 foot-candles.

defect should be advised to have it corrected. The examination should be made by a physician who has made the eye a specialty.

In post-office work requiring fine eye discrimination or long-continued use of the eyes, such as the work of the directory division, the work of the letter separators, the work of the auditing section of the money-order division, and other work of similar nature, only such persons should be employed as have normal vision, at least in one eye, with or without corrective lenses.

In order to obtain the recommended intensity of illumination of 10 foot-candles (when the lighting is first installed) on the working plane, it will probably be necessary to use about 2 watts per square foot of floor area in the general workrooms of the post office.

The best spacing and mounting height of the units and the best size of lamps to use will depend on the height of the ceiling and the height of the working plane.

The relation of the separation cases, tables, and desks to the lights should be such that no shadows would fall upon the working plane. In case it is necessary to move the lighting fixtures in order to accomplish this result, detachable or removable fixtures may be used.

In the illumination of separation cases the relation of the separation cases to the lights should be such that the centers of the units would be 1 foot in front of the plane of the vertical faces of the pigeonholes.

The care of the lighting should be placed in the hands of one man, who should be responsible for the upkeep and good condition of the units. He should make a daily round of the building and replace all burnt-out lamps and broken fixtures. He should cause the lighting units to be cleaned once a week or as often as is necessary. He should see that the walls and ceilings are kept in satisfactory condition, so that they will serve as good reflecting surfaces for the light. He should make measurements once a month with a foot-candle meter, in order to see that the uniformity and constancy of the illumination are maintained.

The switches should be under the control of the foreman, and should be so arranged that the number of lights turned on and the order in which they are turned on would be such as to give the necessary illumination, while at the same time economizing the light.

DIRECTIONS FOR INSTALLING UNITS TO OBTAIN THE DESIRED ILLUMINATION.

Curves (see figs. 22 and 23) representing results obtained under average practice have been prepared, from which may be found, approximately, the proper spacing and the proper wattage of lamps to be used for any height of ceiling and for any height of working

plane in order to secure any desired illumination, with inclosing units of the type of unit No. 1. In the preparation of these curves the output of the lamps of different wattages is assumed to be that given in Table XXXVIII.

For instance, if it is desired to supply an intensity of 7 foot-candles in a room that has a ceiling height of 13 feet the following

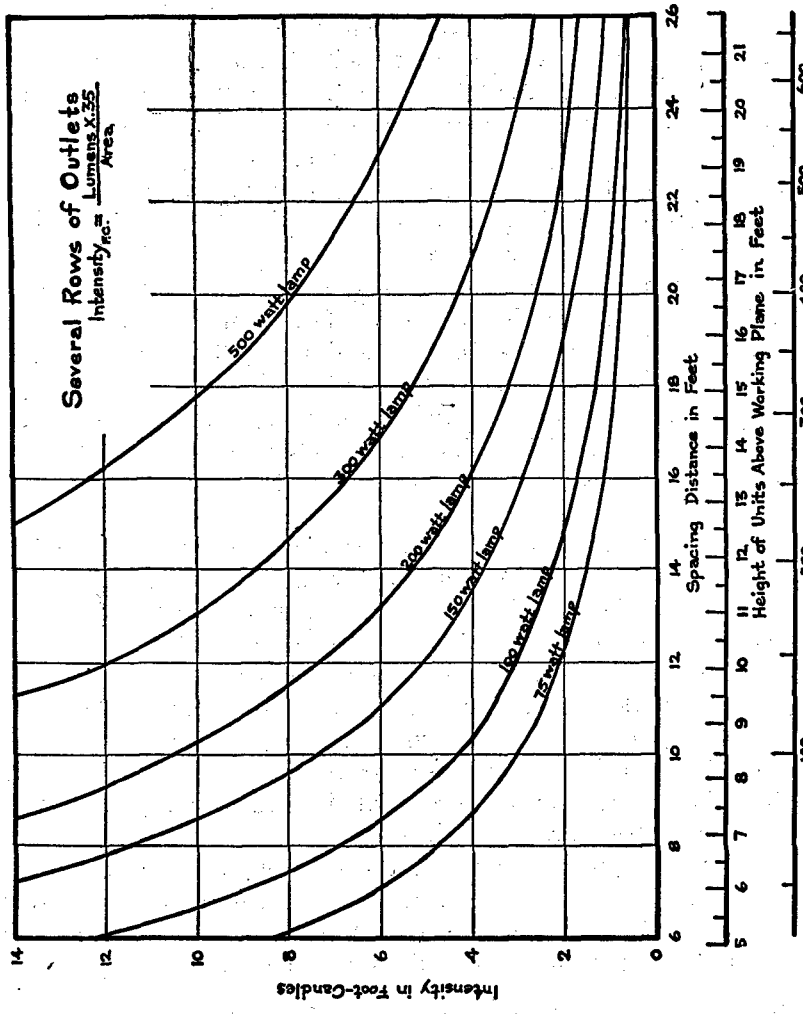


FIG. 22.—Proper spacing and size of lamps, for totally inclosing units of the type of Unit No. 1 for any required intensity of illumination and height of horizontal working plane, for several rows of outlets, and a coefficient of utilization of .35

calculation would be made. Since at least 2 feet should be allowed for the suspension of the unit, the height of the unit from the floor will be 11 feet. If, further, the height of the working plane is 3 feet above the floor, the unit will be 8 feet above the working plane. If the space is to be lighted by several rows of lights, Figure 22 is to be consulted; if by one row of lights, Figure 23 is to be consulted.

Let it be supposed at first that several rows are to be used; then by reference to Figure 22 it is found that the nearest-sized lamp for a height above the working plane of 8 feet and in intensity of 7 foot-candles is 150 watts. It is also seen that the proper spacing of the lights in this case is 9.5 feet. Suppose a single row of light is to be

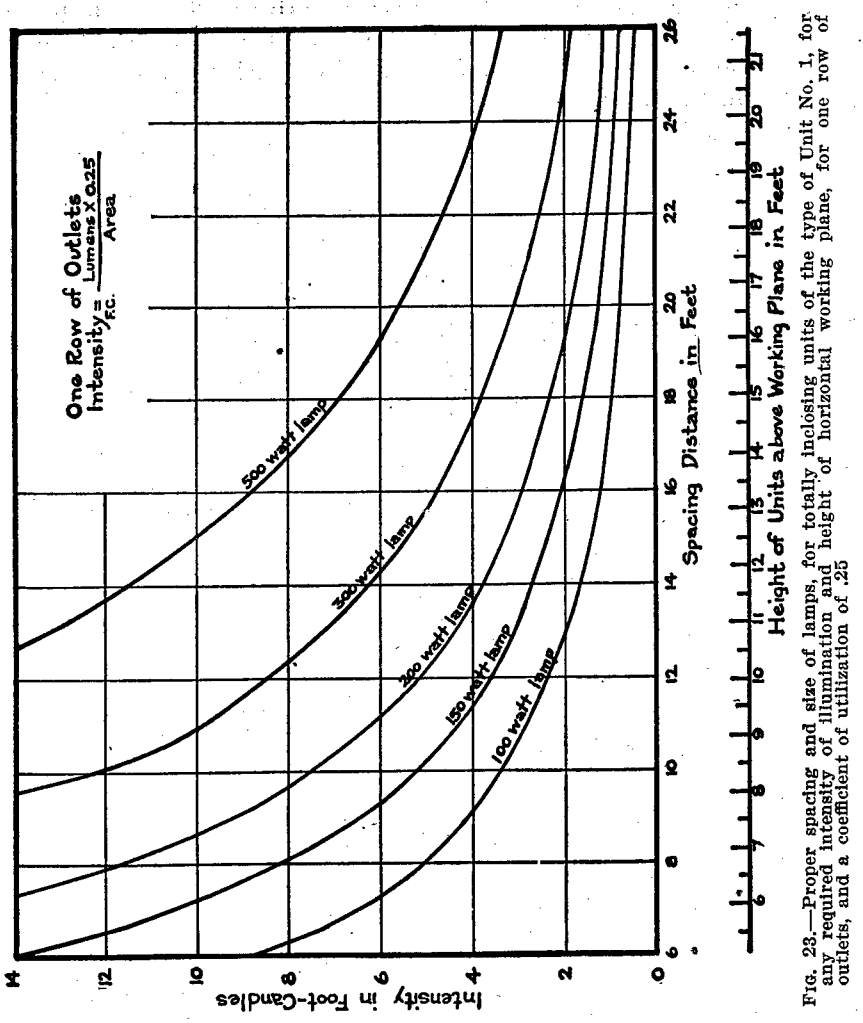


FIG. 23.—Proper spacing and size of lamps, for totally inclosing units of the type of Unit No. 1, for any required intensity of illumination and height of horizontal working plane, for one row of outlets, and a coefficient of utilization of .25

used, then by reference to Figure 23 it is found that the size of the lamp to be used is midway between 150 watts and 200 watts, and that the spacing is 9.5 feet. In this case it would be better to use the 200-watt lamp, in order to be sure to get the desired illumination.

In calculating the curves for Figure 22, a coefficient of utilization of 0.35 was used; and in calculating those for Figure 23, 0.25 was used. If the coefficient of utilization is greater or less than that

given, a proportional correction must be made. The coefficient of utilization will vary from 0.15 to 0.50, according to the color and cleanliness of the ceiling and walls, the width of the rooms, and the height of the lighting units above the working plane.

If, where there are several rows of units, it is impracticable to space the units at the same distance in both directions, the proper area that should be inclosed by four of the units to give the required illumination may be read off on the line marked "area in square feet" on Figure 22.

APPENDIX A.

GLOSSARY OF TERMS AND PHRASES USED IN POST OFFICE WORK.

Call box—A box in which mail that is to be called for is placed.

Cancellation—The defacing of stamps with ink.

Cancellation machine—A machine for defacing the stamps on letters and flat circulars.

Cancellation table—A table used in canceling stamps by hand.

City case—A case in which the mail is separated for the carriers according to their routes.

Delivery division—The division that handles mail for delivery within the territory served by the post office.

Directory service—Determination of addresses through directories in case insufficient address is given on the mail.

Dispatching division—The division that handles mail for distribution to points outside the territory served by the post office.

Distribution case—A case of large pigeonholes or boxes suitable for separating packages—the size of the case and of the pigeonholes being determined by the shape and size of mail to be separated.

Distribution division—Another name for the dispatching division.

Drop—An opening through which mail may be placed in the post office by the public.

Facing—The placing together of letters or circulars so that the addresses and stamps all face the same way.

Facing table—A table used for facing letters or circulars.

Feeder—An employee who keeps the workers at the separation cases supplied with mail.

Form. (*See* Opening form.)

Hold-out—A piece of mail held at the post office to be called for.

Jug—A large separation case, circular in shape with large compartments into which newspapers, parcels, or packages of letters are distributed.

Mailing division—Another name for the dispatching division.

Opening form—A table or case where mail in pouches is received and distributed.

Opening table—A table upon which bundles of letters are opened.

Pouch—A mail bag used for first-class and registered mail.

Pouching—Placing mail in pouches according to destination.

Primary separation—The first separation of mail according to regions, States, groups of States, and large cities.

Rack---------- A metal frame upon which a mail pouch or sack may be hung so that its mouth will be held open.

Route case---------- A separation case in which carriers arrange mail in order of delivery.

Sack---------- A mail bag used for second, third, and fourth class mail.

Secondary separation---------- A separation of mail after the primary separation.

Separating---------- Sorting mail according to geographical or other divisions.

Separation case---------- A case of pigeonholes suitable for separating letters or circulars, the number of pigeonholes being determined by the number of separations that are necessary.

Slug---------- A thick or bulky letter or wrapped newspaper.

Stripper---------- An employee who removes the mail from the separation cases.

Sweeper---------- Another name for a stripper.

Swing room---------- A room used by the post office employees for rest or recreation.

Tying-out---------- Tying together of mail for the same point.

Tour---------- The daily working time.

Tub---------- A large basket, or container, on wheels.

APPENDIX B.

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